9-G-68

Ballantine

MODEL 3028A DIGITAL MULTIMETER

(OPTION 39A)

INSTRUCTION MANUAL

MODEL 3028A DIGITAL MULTIMETER

(OPTION 39A)

Serial No. Prefix 021-
Serial No. Prefix 022-

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90100965B

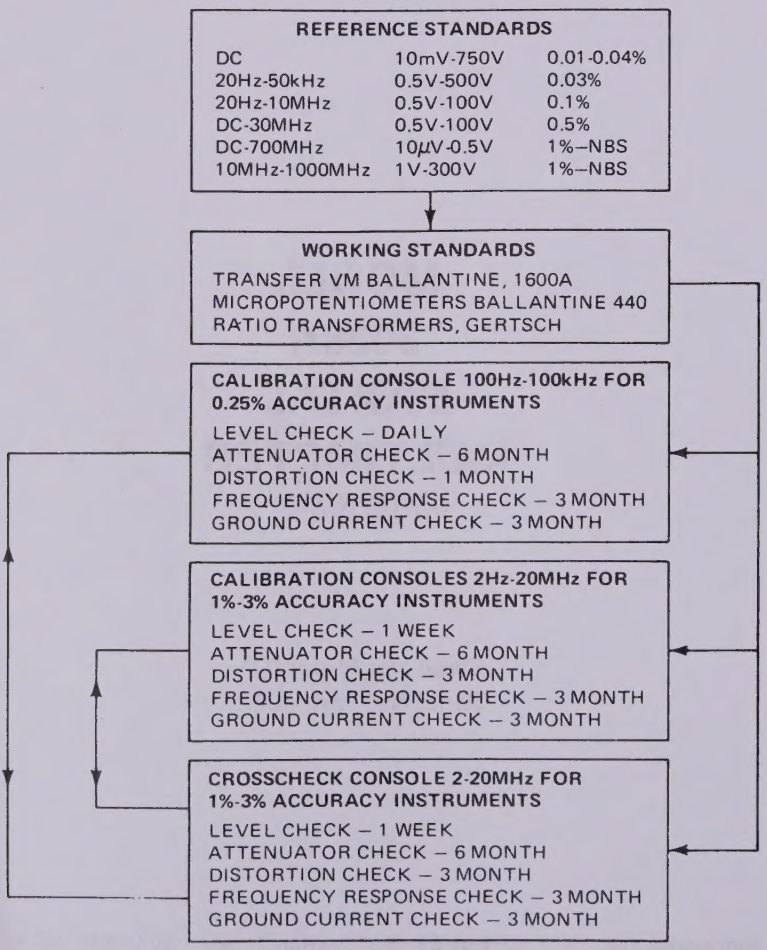
February 1977

WARRANTY

This Ballantine Laboratories, Inc. product is warranted against defects in materials and workmanship for a period of one year from the date of shipment, except for batteries, electron tubes, vacuum thermocouples, and certain other components, if any, listed in this manual. Ballantine Laboratories, Inc. will, at its option, repair or replace products which prove to be defective during the warranty period provided they are returned to Ballantine Laboratories, Inc. prepaid, and provided the proper preventive maintenance and calibration procedures as listed in this manual are followed. Repairs necessitated by misuse of the product are not covered by this warranty. NO OTHER WARRANTIES ARE EXPRESSED OR IMPLIED, INCLUDING BUT NOT LIMITED TO THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. BALLANTINE LABORATORIES, INC. IS NOT LIABLE FOR CONSEQUENTIAL DAMAGES.

CERTIFICATION

Ballantine Laboratories, Inc. certifies that this equipment meets all applicable Ballantine specifications at time of shipment as determined by thorough testing and inspection. Ballantine further certifies that its measurements are traceable to the United States National Bureau of Standards. All instruments used in calibrating Ballantine products are standardized by systematic reference to NBS-traceable standards as described in the validation procedures shown below.


REFERENCE STANDARDS
DC 10mV-750V 0.01-0.04%
20Hz-50kHz 0.5V-500V 0.03%
20Hz-10MHz 0.5V-100V 0.1%
DC-30MHz 0.5V-100V 0.5%
DC-700MHz 10μV-0.5V 1%–NBS
10MHz-1000MHz 1V-300V 1%–NBS
WORKING STANDARDS
TRANSFER VM BALLANTINE, 1600A
MICROPOTENTIOMETERS BALLANTINE 440
RATIO TRANSFORMERS, GERTSCH
CALIBRATION CONSOLE 100Hz-100kHz FOR 0.25% ACCURACY INSTRUMENTS
LEVEL CHECK – DAILY
ATTENUATOR CHECK – 6 MONTH
DISTORTION CHECK – 1 MONTH
FREQUENCY RESPONSE CHECK – 3 MONTH
GROUND CURRENT CHECK – 3 MONTH
CALIBRATION CONSOLES 2Hz-20MHz FOR 1%-3% ACCURACY INSTRUMENTS
LEVEL CHECK – 1 WEEK
ATTENUATOR CHECK – 6 MONTH
DISTORTION CHECK – 3 MONTH
FREQUENCY RESPONSE CHECK – 3 MONTH
GROUND CURRENT CHECK – 3 MONTH
CROSSCHECK CONSOLE 2-20MHz FOR 1%-3% ACCURACY INSTRUMENTS
LEVEL CHECK – 1 WEEK
ATTENUATOR CHECK – 6 MONTH
DISTORTION CHECK – 3 MONTH
FREQUENCY RESPONSE CHECK – 3 MONTH
GROUND CURRENT CHECK – 3 MONTH

Ballantine's Quality Assurance program satisfied the requirements of MIL-I-45208

FAPR 12A-7.160-3
November 1974

WARRANTY

Contract No.: DOT-FA75WA-3708 **Date:** 30 June 1975

(a) Notwithstanding inspection and acceptance by the Government of supplies furnished under this contract or any provisions of this contract concerning the conclusiveness of said inspection and acceptance, the Contractor warrants each item delivered under the contract against defects in design, material or workmanship, and against any damage caused prior to delivery to the Government. Unless otherwise specified, this warranty extends for a period of one year from the date of first use by the Government or two years from date of delivery, whichever occurs first.

(b) Upon notice in writing, the Contractor shall, within 30 days after receipt of such notice repair or replace all defective or damaged items delivered under the contract, f.o.b. any point or points designated by the Government within the 48 contiguous states and the District of Columbia, at no cost to the Government. In the event the contractor is unable to effect such repair or replacement within the aforesaid 30 days, he shall within 15 days after receipt of notice, submit in writing a schedule of repair or replacement, to the Contracting Officer. The Contractor may elect to have any replaced item returned to his plant at his expense.

(c) Unless they fail as a result of improper application by the Contractor, electron tubes, batteries, natural rubber and material normally consumed in operation are excluded from this warranty, but shall in any event be warranted by the Contractor to the extent of any warranty received by the Contractor from his supplier.

(d) If twenty percent (20%) or more of the total quantity of any part or component to which this warranty applies (but not fewer than two of any such part of component) fails in normal service, that fact shall be conclusive evidence that the design, material or workmanship of the item delivered under the contract is unsuitable for the purpose intended. Upon notice of this failure rate the Contractor shall: (i) replace all quantities of the part or component with a corrected part or component in a manner satisfactory to the Government, and at no cost to the Government, and (ii) if necessary to insure correction of the deficiency redesign the item delivered under the contract, or any portion thereof, in a manner satisfactory to the Government and at no cost to the Government. The provisions of this paragraph (d), however, shall not apply to any part or component to be furnished which is specifically identified in the contract by brand name; provided, however, that the Contractor shall warrant such part or component to the extent of any warranty received by the Contractor from his supplier.

(e) For a period of one year from the date of its first use by the Government or two years from the date of its replacement or redesign, whichever occurs first, each item (or portion thereof) or part or component, which is replaced or redesigned pursuant to paragraph (d) above, shall itself be warranted in accordance with the terms of paragraph (d).

(f) The warranty periods specified herein shall exclude any period of time an item fails to perform satisfactorily due to defects or damage to which this warranty applies.

(g) For the purpose of this "Warranty" clause, the term "item" is defined as the contract line item. In the event any item part, or subpart, or component thereof fails, the contractor shall be responsible for all actions necessary to correct such failure and return the contract line item to operating order.

(h) Failure to agree upon any determination to be made under this clause shall be a dispute concerning a question of fact within the meaning of the "Disputes" Clause of this contract.

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Figure 1–1. Model 3028A Digital Multimeter

SECTION 1
GENERAL INFORMATION

1–1. INTRODUCTION.

1–2. The Ballantine Model 3028A is a compact, lightweight, portable, digital multimeter (DMM). The instrument incorporates pushbutton selection of seven functions:

Volts	AC (rms responding)
Volts	DC
Amperes	AC (rms responding)
Amperes	DC
Ohms	LO (180 mV full scale)
Ohms	HI (1.8 V full scale)
Test	Display and battery charge

The 3028A features a bright orange, 0.4-inch, LED display of 3½ digits permitting plus or minus 1999 counts. Overrange is indicated by a blinking display. The decimal point is automatically positioned with range selection. Zero drift is prevented with auto-zero circuitry which is particularly useful for low-level and down-scale measurements. Overload protection is provided on all ranges by means of electronic limiters and without the use of fuses. A resettable circuit breaker is used for protecting the current ranges.

1–3. Pushbutton controls permit the selection of five ac and dc voltage ranges, five ac and dc current ranges, five LO ohms ranges, and five HI ohms ranges. The measurement capabilities of the 3028A cover thirty ranges from 100 microvolts to 1200 volts ac and dc, 100 nanoamperes to 1.999 amperes ac and dc, and 100 milliohms to 1.999 megohms LO ohms (<180 mV) and 1 ohm to 19.99 megohms HI ohms (<1.8 V). AC current and voltage measurement capability features rms response and extends from below 15 Hz to beyond 110 kHz. Automatic polarity indication with + or – sign is standard for all dc functions.

1–4. The Model 3028A is fully protected against accidental overvoltage to 1200 volts (dc plus ac rms) on any ac or dc voltage range and 285 volts (dc plus ac rms) on any ohms range will not damage the instrument. The current ranges are protected to 2 amperes by means of a reliable, fast-acting, resettable circuit breaker. Overload recovery is fast enabling measurements to continue with no time loss.

1–5. Front-panel input connectors are convenient universal binding posts which permit use of banana plugs, captive wire leads, and lug-type connections. The three binding posts connect the volts/ohms, current, and common inputs. Binding post spacing is 3/4 inch (190 mm) to enable use of standard connector plugs, shielded connectors and adapters. The use of captive and shielded input connecting cables is a most desirable safety feature when making off-ground and high-voltage measurements. A separate amperes input connector prevents damage to circuits being voltage tested by inadvertent selection of current measuring mode.

1–6. The COMMON input connector is isolated from earth ground and the ac power line mains can operate to ±1200 volts (dc plus peak ac) with reference to earth ground and to the front and rear panels of the DMM. The isolated common input permits safe off-ground voltage and current measurements since it "floats" the instrument circuitry from earth ground.

1–7. A segment test for the three 7-segment LED digits is provided. Simply push both V and mA pushbuttons to test all segments.

1–8. The instrument is enclosed in an attractive rugged case made of shock-resistant, flame-retardant plastic. The case is lined with a heavy conductive metallic coating which provides radio interference shielding. The 3028A is small and light enough to be easily carried. Quality components and reliable design techniques are used throughout to assure high reliability and low power consumption. A reliability analysis using the criteria of MIL-HDBK-217 shows an expected Mean Time Between Failure (MTBF) of 18,650 hours at 25°C.

1–9. SPECIFICATIONS.

DC VOLTAGE.

Range	Maximum Scale	Resolution
±100 mV	±199.9 mV	100 μV
±1 V	±1.999 V	1 mV
±10 V	±19.99 V	10 mV
±100 V	±199.9 V	100 mV
±1000 V	±1200 V	1 V

Accuracy:
1 year; 15°C to 35°C; ±(0.1% of reading +1 LSD)
24 hours; ±(0.05% of reading + 1 LSD)

Normal Mode Rejection:
Greater than 60 dB at 60 Hz or 50 Hz

Common Mode Rejection (1 kΩ unbalance; COMMON driven):
Greater than 100 dB at dc and 60 Hz or 50 Hz.
Greater than 120 dB at dc and 50 Hz, 60 Hz with internal battery (Option 05)

Maximum Input Voltage: 1200 V (dc plus ac rms sinusoidal)

Input Resistance: 10 megohms on all ranges

Temperature Coefficient:
–10°C to 15°C and 35°C to 55°C
±(0.01% of reading/°C, + 0.005% of Full Scale/°C)

Response Time: 1 second

AC VOLTAGE.

Range	Maximum Scale	Resolution
100 mV	199.9 mV	100 μV
1 V	1.999 V	1 mV
10 V	19.99 V	10 mV
100 V	199.9 V	100 mV
1000 V	1200 V	1 V

Response: AC rms responding

Accuracy:
Frequency response (referenced to 400 Hz)
1 year; 15°C to 35°C
Usable < 15 Hz to > 100 kHz
50 Hz to 20 kHz:
Sine wave, ± (1% of reading + 2 LSD)
With distorted input, add ± (0.75% of reading + 1 LSD)
20 kHz to 50 kHz:
Sine wave, ± (2% of reading + 2 LSD)
With distorted input, add ± (1% of reading + 2 LSD)

Note

Distortion limits add to sine wave accuracy and apply for ≤10% total harmonic distortion with no single harmonic >5%, which relates to a crest factor range of 1.2 to 1.6.

Temperature Coefficient:
−10°C to 15°C and 35°C to 55°C.
±(0.01% of reading/°C + 0.005% of Full Scale/°C).

Input Impedance: 10 MΩ in parallel with less than 100 pF on all ranges.

Common Mode Rejection (1 kΩ unbalance; COMMON driven):
Greater than 120 dB at dc and 60 dB at 60 Hz or 50 Hz with line operation.
Greater than 140 dB at dc and 80 dB at 60 Hz or 50 Hz with internal battery (Option 05) operation.

DC Blocking Voltage (Normal Mode): 1200 volts dc maximum

Maximum Input Voltage: 1200 V rms sinusoidal on all ranges. Not to exceed 10^8 Volt-Hz.

Response Time: 3 seconds, (typically 1 second).

DC CURRENT.

Range	Max. Scale	Resolution	Input Resistance
±100 μA	±199.9 μA	100 nA	1000 Ω
±1 mA	±1.999 mA	1 μA	100 Ω
±10 mA	±19.99 mA	10 μA	10.1 Ω
±100 mA	±199.9 mA	100 μA	1.15 Ω
±1000 mA	±1999 mA	1 mA	0.25 Ω

Accuracy:
1 year, 15°C to 35°C
±(0.3% of reading + 1 LSD)

Temperature Coefficient:
−10°C to 15°C and 35°C to 55°C
±(0.015% of reading/°C + 0.005% of Full Scale/°C)

Voltage Burden at Full Scale: 0.25 volt maximum on all ranges except 0.5 volt on the 1-ampere range.

Maximum Input: 2 amperes (dc plus ac rms) continuous. Protected by resettable circuit breaker and diode clamps. Limit of 15 A peak.

Response Time: 1 second (within one range)

AC CURRENT.

Range	Max. Scale	Resolution	Input Resistance
100 μA	199.9 μA	100 nA	1000 Ω
1 mA	1.999 mA	1 μA	100 Ω
10 mA	19.99 mA	10 μA	10.1 Ω
100 mA	199.9 mA	100 μA	1.15 Ω
1000 mA	1999 mA	1 mA	0.25 Ω

Response: AC rms responding.

Accuracy:
Frequency response (referenced to 400 Hz)
1 year; 15°C to 35°C
Usable < 15 Hz to > 110 kHz
All ranges except 1000 mA, 50 Hz to 10 kHz
Sine wave, ± (1% of reading + 2 LSD)
With distorted input, add ± (0.75% of reading + 1 LSD)
All ranges except 1000 mA, 10 kHz to 50 kHz
Sine wave, ± (2.5% of reading + 2 LSD)
With distorted input, add ± (2% of reading + 2 LSD)
1000 mA range, 50 Hz to 1 kHz
Sine wave, ± (2.5% of reading + 2 LSD)
With distorted input, add ± (2% of reading + 2 LSD)

Note

Distortion limits add to sine wave accuracy and apply for ≤10% total harmonic distortion with no single harmonic >5%, which relates to a crest factor of 1.2 to 1.6.

Temperature Coefficient:
−10°C to 15°C and 35°C to 55°C
±(0.015% of reading/°C + 0.005% of Full Scale/°C)

Voltage Burden at Full Scale: 0.25 volt maximum on all ranges except 0.5 volt on the 1000 mA range.

Maximum Input: 2 amperes (dc plus ac rms). Protected by resettable circuit breaker and diode clamps to 15 A peak.

Response Time: 3 seconds (within one range)

RESISTANCE.

Mode	Range	Max. Scale	FS Volts	FS Amps.	Resolution
LOΩ	100 Ω	199.9 Ω	180 mV	1 mA	0.1 Ω
LOΩ	1 kΩ	1.999 kΩ	180 mV	100 μA	1 Ω
LOΩ	10 kΩ	19.99 kΩ	180 mV	10 μA	10 Ω
LOΩ	100 kΩ	199.9 kΩ	180 mV	1 μA	100 Ω
LOΩ	1000 kΩ	1999 kΩ	180 mV	100 pA	1 kΩ
HIΩ	1 kΩ	1.999 kΩ	1.8 V	1 mA	1 Ω
HIΩ	10 kΩ	19.99 kΩ	1.8 V	100 μA	10 Ω
HIΩ	100 kΩ	199.9 kΩ	1.8 V	10 μA	100 Ω
HIΩ	1000 kΩ	1999 kΩ	1.8 V	1 μA	1 kΩ
HIΩ	10 MΩ	19.99 MΩ	1.8 V	100 pA	10 kΩ

Accuracy:
1 year, 15°C to 35°C
All LOΩ ranges, except 1000 kΩ range, and all HIΩ ranges, except 10 MΩ range, ± (0.5% of reading + 1 LSD)
LOΩ 1000 kΩ range and HIΩ 10 MΩ range, ± (2% of reading + 1 LSD)

Temperature Coefficient:
−10°C to 15°C and 35°C to 50°C ± (0.04% of reading/°C + 0.03% of range/°C)

Response Time:
All LOΩ ranges, except 1000 kΩ range, and all HIΩ ranges, except 10 MΩ range, 4 seconds
LOΩ 1000 kΩ range and HIΩ 10 MΩ range, 6 seconds

Maximum Input Voltage (All Ranges) Continuous:
285 volts (dc + ac rms sinusoidal)
Intermittent (10 seconds 20% duty factor), 500 volts (dc + ac peak)
Protected by electronic circuits.

ENVIRONMENTAL.

Temperature:
Operating: −10°C to +55°C
Storage: −54°C to +85°C with batteries to 50°C

Humidity:
0 to 80% R.H.
0 to 85% R.H. to 45°C
Usable 0 to 98% R.H. without condensation.
Meets requirements of MIL-T-28800, Class 3

Altitude:
Operating: 0 to 3 km (10,000 feet). Derated above 1 km.
Linearity derated above 1 km from rated voltages above 300 volts to half rating at 3 km.
Storage: 0 to 15 km (50,000 feet)

Shock and Vibration: Meets requirements of MIL-T-28800, Class 3, Style D.

Case: Flame-retardant, shock-resistant plastic with full metallized shielding and earth-grounded aluminum panels. Handle detents in 12 positions and serves as tilt stand. Meets the requirements of MIL-T-28800, Style D.

Safety: Meets requirements of MIL-T-28800, Class 3, Style 3.

EMI: Meets requirements of MIL-STD-461A for CS-01, CS-06 and RS-03 to 400 MHz at 1 V/meter.

GENERAL.

Display:
4 digits and ±polarity sign
7 segment, bright orange
LED 1.1 cm (0.4 inch) character height

Display Test: Three-digit, seven-segment test when pushing both V and mA pushbuttons.

Dimensions and Weights:
Height: 63 mm (2-3/8 in.)
Width: 203 mm (8-1/8 in.); with handle 239 mm (9-5/8 in.)
Depth: 222 mm (8-11/16 in.); with handle 298 mm (11-3/4 in.)
Weight: 1.2 kg (2 lb 7 oz)
With batteries 1.85 kg (4 lb 1 oz)
Shipping Weight: 2.94 kg (6.5 lb)

Power: 103 to 138 volts (120 volts nominal), 50 to 400 Hz — complies with MIL-T-28800, Class 3 power requirements, 5 watts

Supplied Accessories:
1 Power Cable, 6½ feet, P/N 33100000A
2 Instruction Manual, P/N 90100965A
1 Probe Test Lead, 4 feet, (red)
1 Probe Test Lead, 4 feet, (black) } P/N 85100620A
2 Alligator Tip Adapters
1 Easy Hook Test Lead, 4 feet, (red), P/N 85100600A
1 Easy Hook Test Lead, 4 feet, (black), P/N 85100610A

1–10. AVAILABLE ACCESSORIES.

1–11. Table 1–1 lists the accessories available for use with the 3028A.

1–12. OPTIONS.

1–13. Several options are available for the Model 3028A. These options are listed in Table 1–2. Desired options may be specified at time of purchase. Contact your Ballantine representative for additional options which may be available. Table 1–3 defines options incompatibility.

1–14. INSTRUMENT AND MANUAL IDENTIFICATION.

1–15. These Ballantine instruments are identified by a two section serial number. The first three digits section of this number identify the configuration code. This code number appears on the front page of this manual and must coincide with the first three digits of the serial number of your instrument. Addendum sheets supplied with the manual will define technical corrections or differences between your instrument and the unit described in this manual. If applicable, back dating information is located at the end of this manual. This backdating information pertains to instruments with serial number prefixes listed on the title page of this manual.

TABLE 1–1. ACCESSORIES

Model	Description
10800B	40 kV, HV DC Probe
1301B	10 kV, HV AC Probe
10850B	RF Probe, 100 kHz to 700 MHz
10860A	Current Probe, AC, Clamp on to 600A
10801B	Test Lead Kit, 4 probes
10730A	Carrying Case, padded vinyl, 6" x 9" x 12"
10731A	Carrying Case, molded plastic
606	Shunt, AC/DC, 20 Amps (0.01Ω)
10751A	Front Panel Dust Cover
800-09	Rack Mount Kit, left or right (one instrument)
800-10	Rack Mount Kit, side-by-side (two instruments)
12616A	Adapter, Shielded, double banana to BNC female
12617A	Adapter, double banana to BNC female
12249D	Cable, BNC to BNC shielded cable, 4 feet
12250D	Cable, BNC to alligator clips, 4 feet
12251D	Cable, double banana to BNC, 4 feet
12252D	Cable, Shielded, double banana to test probe
—	Battery Replacement Kit P/N 89104221A

TABLE 1–2. OPTIONS

Option	Description	Factory Installed	Field Installed
01	Parallel BCD Printer Output	Yes	No
05	Internal Rechargeable Battery Pack with charger. 16 hour charge, 5 hour operation.	Yes	Yes
06 Series	Universal AC power voltage IEC compatible multi-tap transformer primary		
060	86 to 108 V, 48 to 400 Hz	Yes	Yes
061	103 to 130 V, 48 to 400 Hz	Yes	Yes
062	196 to 245 V, 48 to 400 Hz	Yes	Yes
063	208 to 260 V, 48 to 400 Hz	Yes	Yes
20	Analog Panel Meter in addition to digital display	Yes	No
21	10 Ampere Current Range	Yes	No
22	Temperature Probe Accessory −40°C to +90°C	Yes	No
23	Temperature Probe Accessory −40°F to 200°F	Yes	No
24	10 mV dc Range with 10 μV resolution	Yes	No
25	AC Power Line Filtering and Surge Voltage Suppression	Yes	Yes
39	102 to 138 volt ac power line, 50 to 400 Hz. Includes battery pack Option 05 and 100 hours burn-in and EMI spec. AC converter only average responding 50 Hz to 50 kHz. Complies with FAA Specification FAA-P-2625.	Yes	No
39A	As above, with ac rms response	Yes	Yes
62	Includes Options 05, 06, 20 and accessory power connector on rear panel for use with UHF Probe Model 10855B which operates only when the DMM is ac-powered.	Yes	No

TABLE 1–3. OPTION INCOMPATIBILITY

Option	01	05	06	20	21	22	23	24	25	39	39A	62
01	–	N	Y	Y	Y	Y	Y	Y	Y	N	N	N
05	N	–	Y	Y	Y	Y	Y	Y	Y	P	P	P
06	Y	Y	–	Y	Y	Y	Y	Y	Y	Y	Y	P
20	Y	Y	Y	–	N	Y	Y	Y	Y	Y	Y	P
21	Y	Y	Y	N	–	Y	Y	Y	Y	N	N	N
22	Y	Y	Y	Y	Y	–	Y	N	Y	N	N	N
23	Y	Y	Y	Y	Y	Y	–	N	Y	N	N	N
24	Y	Y	Y	Y	Y	N	N	–	Y	N	N	N
25	Y	Y	Y	Y	Y	Y	Y	Y	–	Y	Y	Y
39	N	P	Y	Y	N	N	N	N	Y	–	Y	N
39A	N	P	Y	Y	N	N	N	N	Y	Y	–	N
62	N	P	P	P	N	N	N	N	Y	N	N	–

– = Not Applicable N = Not Compatible Y = Compatible P = Included

SECTION 2
INSTALLATION

2–1. INTRODUCTION.

2–2. This section contains information and instructions necessary for the installation and shipping of the instrument. Details are provided for initial inspection, power connection, grounding safety requirements, installation information, and repacking instructions for storage or shipment.

2–3. UNPACKING AND INITIAL INSPECTION.

2–4. Unpacking and initial inspection of the instrument requires only the normal precautions and procedures applicable to the handling of sensitive electronic equipment. The contents of all shipping containers should be checked for included accessories and certified against the packing slip to ascertain that the shipment is complete.

2–5. PERFORMANCE CHECKS.

2–6. This instrument was carefully inspected for mechanical and electrical performance before shipment from the factory. It should be free of physical defects and in perfect electrical order upon receipt. Check the instrument for possible damage incurred in transit and, if necessary, complete the performance checks outlined in paragraphs 5–7 through 5–30. If there is any indication of damage or improper operation, refer to the warranty included in this manual and notify your local Ballantine field engineering representative or the factory.

2–7. POWER REQUIREMENTS.

2–8. The instrument may be operated from any ac source of 103 to 130 volts* and can be also wired for operation over the ranges of 86 to 108 volts (100 V), 190 to 245 volts (220 V), or 208 to 260 volts (240 V) when the tapped primary power transformer of Option 06 is installed. All instruments operate over the power frequency range of 50 Hz to 400 Hz. Always check the line voltage setting identified on the rear panel.

CAUTION

Failure to wire the instrument to match the operating line voltage will damage the instrument and may void the warranty.

2–9. The instrument may also be operated from internal rechargeable nickel cadmium batteries (Options 05 and 39). For battery operation, the line cord is disconnected. Fully charged batteries will operate the instrument for approximately 5 hours. With the line cord connected, the batteries can be fully charged from the line voltage within 14 hours with the POWER switch set to the OFF position. DO NOT charge the batteries for more than 20 continuous hours or the life of the batteries may be shortened. Upon receipt

*Option 39A rated for 102 to 138 volts.

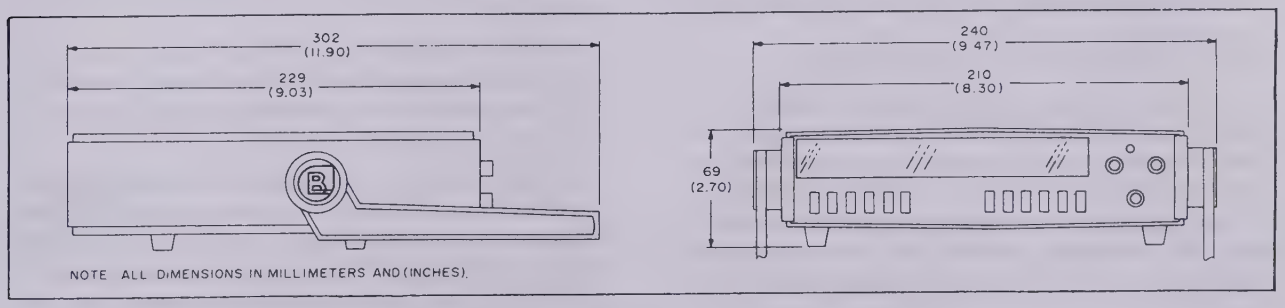


Figure 2–1. Model 3028A, Outline Dimensions

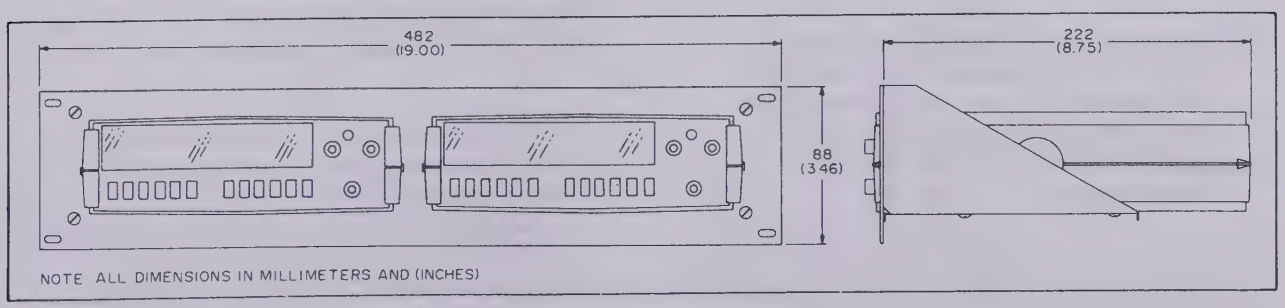


Figure 2–2. Rack Mount Kit, Outline Dimensions

of the instrument, or after extended storage, the batteries should be charged for at least 8 hours prior to use.

CAUTION

When powering the instrument from extremely noisy ac power lines near pumps, elevators, or RFI emitters it is recommended that Option 25 be installed. This option provides power line transient suppression and additional filtering in applications which may otherwise damage the instrument.

2–10. GROUNDING REQUIREMENTS.

2–11. To insure the safety of operating personnel, the U. S. Occupational Safety and Health Act (OSHA) and good engineering practice require that the instrument panel and enclosure be "earth grounded." All Ballantine instruments are provided with a three-conductor power cable assembly which, when plugged into an appropriate power receptacle, grounds the instrument. The offset pin on the male end of the power cable is the ground wire connection to the connector on the rear panel of the instrument.

2–12. To preserve the safety protection feature, when operating the instrument from a two-contact outlet, use a three-prong to two-prong adapter and connect the green lead or terminal on the adapter to "earth ground."

2–13. When using the instrument on internal battery operation, there is no ground return through the power cord. Use caution to avoid electrical shock and consider connecting the instrument cabinet to earth ground through the rear-panel grounding lug or power receptacle grounding pin.

2–14. INSTALLATION AND MOUNTING.

2–15. The instrument is fully solid state and dissipates minimal heat. No special cooling is required. However, the instrument should not be operated where the ambient temperature exceeds 55°C (131°F) or when condensation due to high relative humidity appears anywhere on the instrument. The instrument is shipped ready for use as a portable or bench instrument. Outline dimensions are shown in Figure 2–1.

Note

Before using the instrument, exercise each of the 12 pushbutton switches six or more times. This wiping action cleans switch contacts which may become noisy or intermittent during periods of storage or in contaminating environments.

2–16. The instrument case is provided with a carry handle which also serves as a tilt stand. To change the position of the handle, simply pull both sides of the handle outward from the case to disengage the detent mechanism; then, rotate the handle to the desired position, push the handle back toward the case and rotate slightly until it detents in place. The handle may be removed by firmly, but carefully, pulling both sides of the handle out of the detent mechanisms on the case.

2–17. Rack mounting capability for the instrument is provided by a rack adapter panel. Three 19-inch EIA rack-mount configurations are available. See Figure 2–2 for outline drawings.

2–18. REPACKAGING FOR SHIPMENT.

2–19. If the instrument is to be repackaged for shipment, as a general guide, repackage the instrument as described in the following procedure and shown in Figure 2–3. Use either the original packing material, if available, or material similar to that specified. Proceed as follows:

a. Place the instrument accessories, if any, in a plastic bag and seal the bag.

Note

It is recommended that NiCad batteries be removed from the instrument if extreme environments or storage in excess of twelve months is anticipated.

b. For long distance shipping only, use U. S. Government packaging method IIC and tape a two-unit bag of dessicant (MIL-D-3464) on the rear cover.

c. Place a piece of sturdy cardboard over the front panel for protection. Enclose the instrument in a plastic bag and seal the bag.

d. Wrap the bagged instrument and accessories in 1-inch thick, flexible, cellular plastic-film, cushioning material (PP-B-795) and place in a barrier bag (MIL-B-131). Extract the air from the bag and heat seal.

e. Place the wrapped instrument and accessories into a fiberboard box (PPP-B-636) of suitable size. Fill spaces with rubberized hair or cellular plastic cushioning material. Close box in accordance with container specifications. Seal with sturdy water-resistant tape or with metal straps.

f. Mark container "FRAGILE," "HANDLE WITH CARE," or similar precautionary notice. Affix shipping labels as required or mark according to MIL-STD-129.

Note

If the instrument is to be shipped to Ballantine for calibration or repair, attach a tag to the instrument identifying the owner. Note the problem, the symptoms, and service or repair desired. Record the model and serial number of the instrument. Show the work authorization order as well as the date and method of shipment.

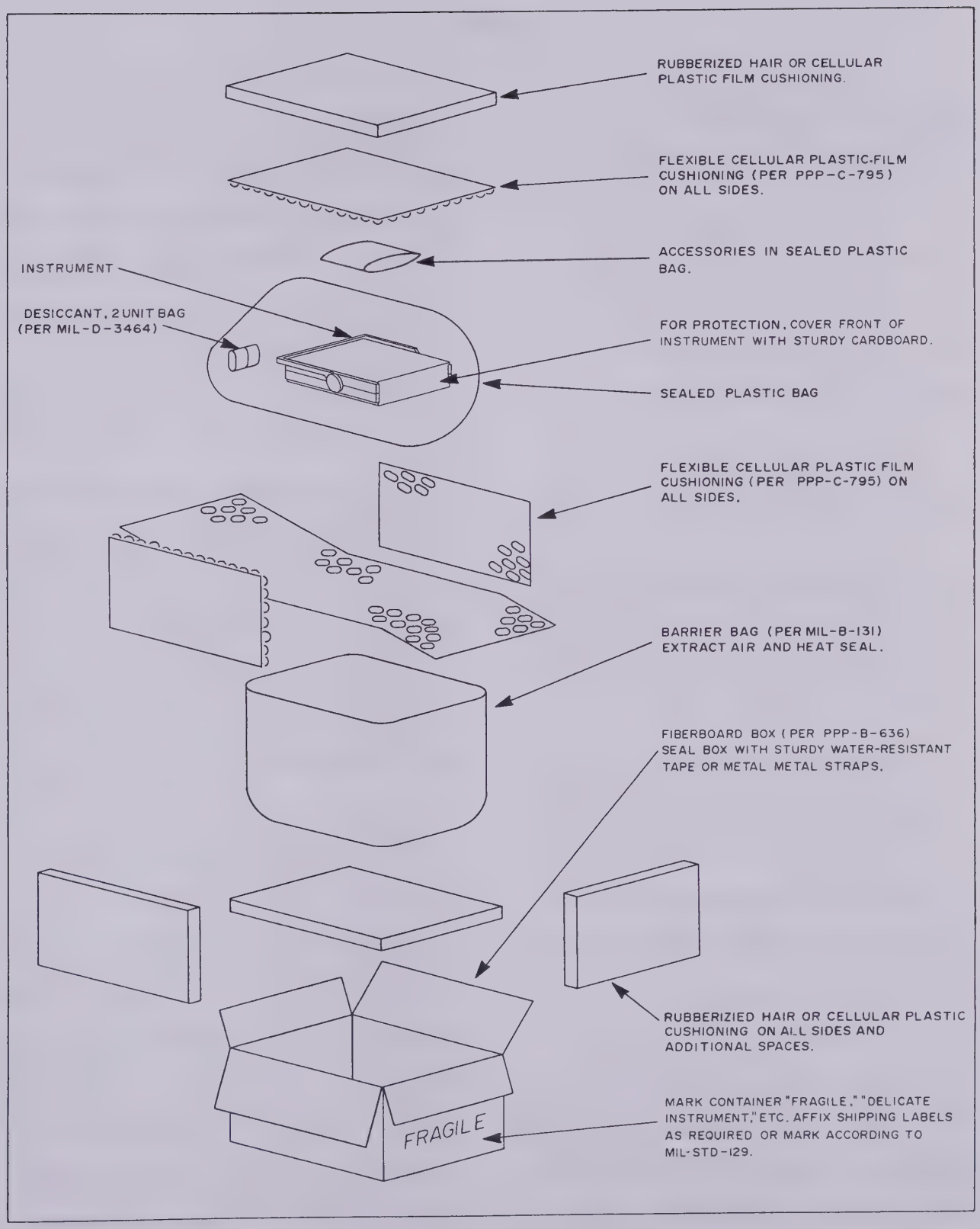

RUBBERIZED HAIR OR CELLULAR PLASTIC FILM CUSHIONING.
FLEXIBLE CELLULAR PLASTIC-FILM CUSHIONING (PER PPP-C-795) ON ALL SIDES.
ACCESSORIES IN SEALED PLASTIC BAG.
INSTRUMENT
DESICCANT, 2 UNIT BAG (PER MIL-D-3464)
FOR PROTECTION, COVER FRONT OF INSTRUMENT WITH STURDY CARDBOARD.
SEALED PLASTIC BAG
FLEXIBLE CELLULAR PLASTIC FILM CUSHIONING (PER PPP-C-795) ON ALL SIDES.
BARRIER BAG (PER MIL-B-131) EXTRACT AIR AND HEAT SEAL.
FIBERBOARD BOX (PER PPP-B-636) SEAL BOX WITH STURDY WATER-RESISTANT TAPE OR METAL METAL STRAPS.
RUBBERIZIED HAIR OR CELLULAR PLASTIC CUSHIONING ON ALL SIDES AND ADDITIONAL SPACES.
FRAGILE
MARK CONTAINER "FRAGILE," "DELICATE INSTRUMENT," ETC. AFFIX SHIPPING LABELS AS REQUIRED OR MARK ACCORDING TO MIL-STD-129.

Figure 2–3. Model 3028A, Packing Diagram

NOTES

SECTION 3
OPERATION

3–1. INTRODUCTION.

3–2. This section contains instructions and information required for the operation of the instrument. Included are identification of controls, connectors, options and indicators.

3–3. CONTROLS, INDICATORS, AND CONNECTORS.

3–4. The controls, indicators, and connectors are identified in Figure 3–1 and Table 3–1.

3–5. POWER REQUIREMENTS (AC AND INTERNAL BATTERY).

3–6. See paragraphs 2–7 through 2–9. For grounding and safety earth connections see paragraphs 2–10 through 2–13. Apply ac power of the proper line voltage. Always check rear panel voltage label.

3–7. OPERATING INSTRUCTIONS.

3–8. Turn on power by pushing the POWER pushbutton in to the ON position. The digital display will light up to indicate POWER ON.

3–9. When using internal batteries (Options 05 or 39), check the battery charger condition by removing ac power and simultaneously pushing the 1000 k and 10 M pushbuttons. The display should read above 5 volts or the batteries must be fully charged for 16 hours by applying ac power and turning the power switch to OFF.

3–10. To check the display indicators, simultaneously push the V and mA pushbuttons. All seven segments of the three right-hand numerals must light up.

Note

Additional instructions may be required when options are installed. These instructions are listed later in this section or in Section 7.

3–11. See Table 3–2 and select the desired range and function. Connect the test leads to the corresponding input connectors and observe precautions when measuring hazardous voltages.

3–12. DC MEASUREMENTS.

3–13. DC Voltage.

3–14. See Table 3–2 for dc voltage operation limits.

3–15. Select dc voltage.

a. Depress the V (S3) pushbutton.

b. Check that the AC/DC pushbutton (S2) is out (DC mode).

c. Depress the 1000 pushbutton (S11).

3–16. Connect the input signal to the COMMON (–) and V–Ω input connectors. Select range by first depressing the 1000 (S11) pushbutton and then progressively increasing DMM sensitivity until the display shows 3 or 4 significant digits of information.

3–17. DC Voltage Measurement Precautions.

a. Do not exceed 1200 volts dc on any range.

b. Do not float the COMMON input binding post more than 1200 V peak above earth ground.

c. The input resistance of the 3028A is 10 megohms. Measurements from high-source resistances can cause additional measurement errors. This loading error may be calculated by:

$$\%\ \text{loading error} = \frac{100 \times \text{Source Resistance}}{\text{Source Resistance} + 10\ \text{Megohms}}$$

As example, a source resistance of 1000,000 ohms will cause a measurement error of 1% of reading.

d. An ac signal superimposed on the dc voltage to be measured may cause reading errors. Such unwanted ac signals are termed normal mode signals since they appear with the signal to be measured. The DMM has a normal mode rejection capability (NMRR) greater than 60 dB (1000 to 1) at 60 Hz. As an example a 1-volt ac signal in common mode with a 100 mV dc input signal may cause ±1 millivolt of reading error.

e. When the DMM is floated above earth ground an unwanted signal may appear between earth ground and the COMMON input of the DMM. This common mode signal may cause measurement errors. The DMM rejects common mode signals with a rejection ratio (CMRR) of:

120 dB at dc	(1 million to 1)
100 dB to 60 Hz (sinewave)	(100,000 to 1)

This means that a 100-volt peak 60 Hz common mode signal will result in only 1 millivolt of measurement error.

CAUTION

Never exceed 1200 volts dc or ac peak common mode potential.

3–18. Overvoltage Indication. A flashing display indicates overvoltage (overload). Switch to the next higher range until a steady display appears.

3–19. Overrange. The DMM may be used to 200% overrange on all dc ranges and modes up to the limitation of 1200 volts and 2 amperes. A reading of 1000 represents full range and 1999 is considered full scale. The display will flash above 100% overrange when full scale (1999) is exceeded. The

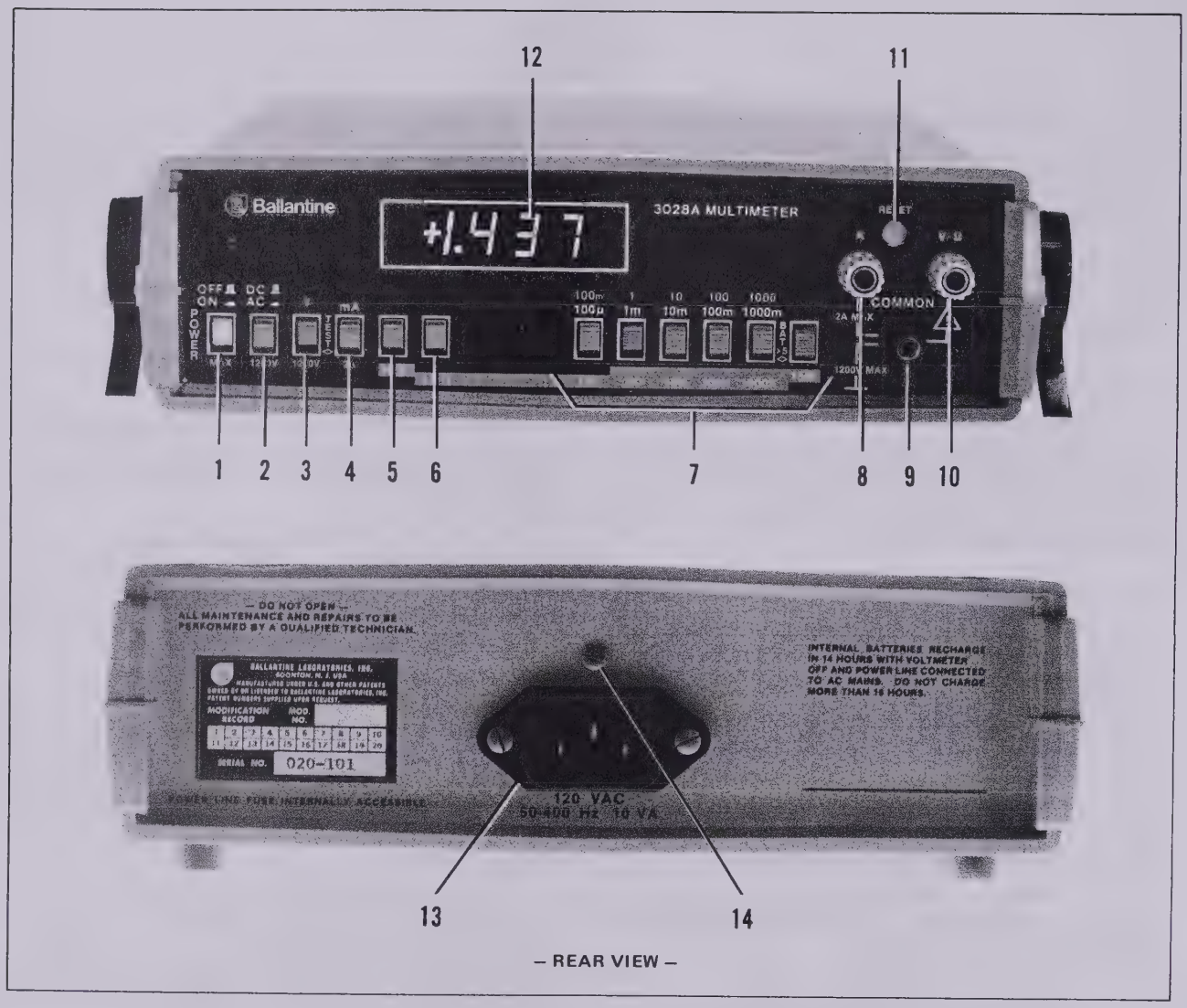


Figure 3–1. Model 3028A, Controls, Indicators, and Connectors

DMM may be used to 2999 with the display flashing and with reduced accuracy.

3–20. Display zero is automatically adjusted. To check zero simply short the V–Ω to the common terminals with a short strap and the display will read zero plus or minus two counts on all ranges. The display will flash periodically but generally not more than ten times in ten seconds.

3–21. Automatic polarity is a feature of the instrument. Simply apply any dc voltage (negative to COMMON) and read the polarity sign on the display. Turnover error from plus to minus is held to within ±2 counts by the DMM circuitry.

3–22. DC Current.

3–23. See Table 3–2 for dc current operation limits.

3–24. Select dc current.

a. Depress the mA (S4) pushbutton.

b. Check that the AC/DC pushbutton (S2) is out (DC Mode).

c. Depress the 1000 (S11) pushbutton.

3–25. Connect the input signal to the A and COMMON (–) input connector.

3–26. Select range by first depressing the 1000 (S11) pushbutton and then progressively increasing DMM sensitivity until the display shows 3 or 4 significant digits of information.

TABLE 3–1. CONTROLS, INDICATORS, AND CONNECTORS

Index No.	Control, Indicator, Connector	Symbol No.	Function
1	POWER Switch	S1	ON/OFF switch. Charges battery in OFF position.
2	AC/DC Switch	S2	Selects ac or dc volts and mA.
3	V Volts Switch	S3	Selects Volts Mode.
4	mA Amperes Switch	S4	Selects mA Mode.
5	HIΩ Switch	S5	Selects high voltage (1.8V) Ohms Mode.
6	LOΩ Switch	S6	Selects LOΩ voltage (180mV) Ohms Mode.
7	Range Switches	S7, S8, S9 S10, S11, S12	Select one of five voltage and current ranges and one of six ohms ranges.
8	COMMON	J30	Binding post input connector for all measuring modes.
9	V–Ω Connector	J10	Binding post input connector for volts and ohms modes.
10	A Connector	J20	Binding post input connector for current mode.
11	RESET	CB10	Circuit breaker. Push to reset for current overloads >2A.
12	Digital Display	DS750-DS753	Digital readout consisting of 3 seven-segment numerics and 1 plus a polarity indicator.
13	AC Power Receptacle	J50	Power cable receptacle with ac power and "earth" ground.
14	Earth Ground Lug	—	Earth ground connection.

TABLE 3–2. MODEL 3028A OPERATIONAL LISTING

Selected Function	Selected Range	Input Connections	Maximum Input Overload Limits
V DC	100 mV, 1, 10, 100, or 1000 V	V–Ω and COMMON	1200 V dc or ac rms (sinusoidal)
V AC	100 mV, 1, 10, 100, or 1000 V	V–Ω and COMMON	1200 V dc or ac rms (sinusoidal)
mA DC	100 μA, 1, 10, 100, or 1000 mA	A and COMMON	2 A dc or ac rms Circuit breaker protected to 15 A peak.
mA AC	100 μA, 1, 10, 100, or 1000 mA	A and COMMON	2 A dc or ac rms Circuit breaker protected to 15 A peak.
HIΩ (>1.8V)	1 k, 10 k, 100 k, 1000 k, or 10 MΩ	V–Ω and COMMON	285 V dc plus ac rms (sinusoidal) / 500 V dc plus ac rms (sinusoidal)
LOΩ (<180 mV)	100, 1 k, 10 k, 100 k, or 1000 k	V–Ω and COMMON	285 V dc plus ac rms (sinusoidal) / 500 V dc plus ac rms (sinusoidal)
Any	All Ranges	Earth Ground (powerline) and COMMON	1200 V peak

3–27. DC Current Measurement Precautions.

a. Do not exceed 2 amperes on any range. The circuit breaker will protect the mA range on overloads above 2A. To RESET the circuit breaker, allow 10 seconds and push the button above the A binding post input connector.

WARNING

Do not exceed 15 amperes peak input.

b. Do not float the ammeter (dc current meter) COMMON input binding post more than 1200 volts peak above ground.

c. The dc mA input is protected for overvoltage by clipping diodes which clamp at ±200 mV. The protective circuit breaker will trip whenever these diodes clamp and the resultant overload current exceeds 2 amperes.

d. The shunts which meter current in the DMM vary with range. See the specification table in Section 1 for shunt resistance for each range. A measurement error will occur if the source resistance (R_S) is not at least 1000 times greater than the shunt resistance (R_r) of the DMM.

$$\% \text{ error} = \frac{100 \times R_r}{R_S + R_r}$$

For example, on the 1 mA range where the shunt resistance (R_r) is 100 ohms, a source resistance (R_S) of 10,000 ohms will result in a dc mA measuring error of 1% of reading.

e. An ac signal superimposed on the dc current to be measured may cause reading errors. Such unwanted ac signals are termed normal mode signals. The DMM has a normal mode rejection capability in the dc mA mode but ac normal mode current signals should be avoided. When they add excessively to the rms current flowing through the shunt resistors, sufficient current may flow to trip the protective circuit breaker. The peak voltages superimposed on the shunt resistors should not exceed 500 millivolts peak-to-peak.

f. The DMM is almost always floated above earth ground when making current measurements. See paragraph 3–17(d) for a description of measurement errors caused by common mode signals. In typical use, the DMM will read ±10 counts of error when 100 volts peak of common mode signal is present. For common mode error calculations on the dc mA ranges always use the most sensitive dc voltage range (100 mV), since the voltage developed across the DMM shunts is 100 millivolts full range.

g. The A to COMMON input connector resistance in the dc mA mode is listed in the specifications. The connector-to-connector resistance is greater than the shunt resistance due to the internal connecting leads. Always consider the connector-to-connector voltage drop when making precision current measurements.

3–28. Overcurrent Indication. A flashing display indicates overload. Switch to the next higher range until a steady display appears.

CAUTION

Do not switch the current range switches when currents exceed 100 mA. This will extend the life of the pushbutton switches.

3–29. The DMM may be used to 200% overrange on all dc mA ranges to 1999 mA (2 amperes). The display will flash above 100% overrange when full scale (1999) is exceeded.

3–30. The display zero is automatically adjusted. To check zero in dc mA mode short the A and COMMON input connectors with a short strap and the display will read 000 plus or minus three counts on all ranges.

3–31. Automatic polarity indication in dc mA mode is a feature of this instrument. Simply apply any dc current (negative to COMMON) and read the polarity sign on the display. Turn over error is held to ±3 counts by the DMM circuitry.

3–32. Currents in excess of 1999 mA may be measured using the Ballantine Model 606 Shunt. This shunt incorporates a 0.01-ohm resistor so that currents to ±20 amperes may be measured using the 100 mV dc range. The 3028A Option 21 is also available and it incorporates a 10-ampere current range.

3–33. AC MEASUREMENTS.

3–34. Response.

3–35. The 3028A Multimeter responds to the rms value of the ac input signal. A unique Ballantine computing ac to dc converter is incorporated in the instrument to permit accurate ac measurements even in the presence of total harmonic distortion of 10%. RMS response and calibration is used to provide a true measure of the power capability of heating value of the input signal.

3–36. The 3028A will provide accurate ac measurements of badly distorted signals. It will respond to the rms value of the input signal regardless of the phase of the input signal components. It is ideal for accurately measuring power line voltages and telephone test voltages, including ringing frequencies and two-tone signals. It is accurate even when total harmonic distortion exceeds 10%, provided no single harmonic exceeds 5%. The input signal should be symmetrical and periodic.

When the input signal is a sine wave with sharp spikes or flattened peaks it is important to check the signal with an oscilloscope to be sure that the crest factor of the signal falls within the broad limits of 1.2 to 1.6. It is usable over the range of 1 to 2.25 and beyond.

$$\text{Crest Factor} = \frac{\text{Signal Peak Volts}}{\text{Signal RMS Volts}}$$

Figure 3–2 shows the voltage relations of a sine wave. It indicates that the crest factor of a sine wave is 1.414.

The 3028A computing ac rms to dc converter has ample dynamic amplitude range for handling all specified crest factors. It is superior in all respects to peak or average responding detectors used in less sophisticated multimeters which will generally read the same as the 3028A on pure sine waves but which will read higher than the 3028A on ac input signals having crest factors < 1.4 and lower than the 3028A for input signals with crest factors > 1.4. The accurate improvement of rms response can provide 4% better accuracy over average responding meters. For full true rms capability, including dc coupling to handle aperiodic and unsymmetrical signals with crest factors to 50, the Ballantine Models 3620A and 3630A are recommended.

3–37. AC Voltage Measurements.

3–38. See paragraph 1–9 for full operating specifications.

3–39. To Select AC Voltage.

a. Depress the V pushbutton and the 1000-volt range pushbutton.

b. Be sure the AC/DC pushbutton is in to select AC.

3–40. Measurement Precautions.

a. Do not exceed 1200 volts rms input on any range.

b. Do not exceed 1200 volts peak between earth ground and the COMMON connector.

c. Take care to minimize test lead capacitive loading of the circuit under test. Use test points which present the lowest possible source impedance. The V–Ω COMMON input terminals of the multimeter are shunted by 100 pF and 10 megohms. Open test leads may add another 25 pF to 50 pF (or more if leads are twisted or run over a "ground plane").

The loading factor of the shunt capacitance may be determined by the following relationship:

$$X_C\,(\text{ohms}) = \frac{1}{2\pi Fc\,(\text{Frequency})\,F\,(\text{Capacity})}$$

Example for 100 pF shunt capacity at 10 kHz:

$$X_C = \frac{1}{6.28 \times 10{,}000 \times 100 \times 10^{-12}}$$

$$= \frac{1}{6.28 \times 10^{-6}} = 160{,}000\ \Omega \text{ of capacitive reactive loading.}$$

160,00 Ω is only 1.6% of the 10 MΩ shunt resistance but may present a considerable error when it loads an ac test point. In fact, to achieve less than 1% error in multimeter reading accuracy due to capacitive loading, the test point source impedance should be less than one one-hundredth of the combined capacitive loading impedance of the multimeter and test leads. In the foregoing example, the test point impedance must be less than 1600 Ω if the error is to be less than 1% or 160 Ω if less than 0.1%.

The loading effect becomes more important at higher frequencies but is present even at line frequency.

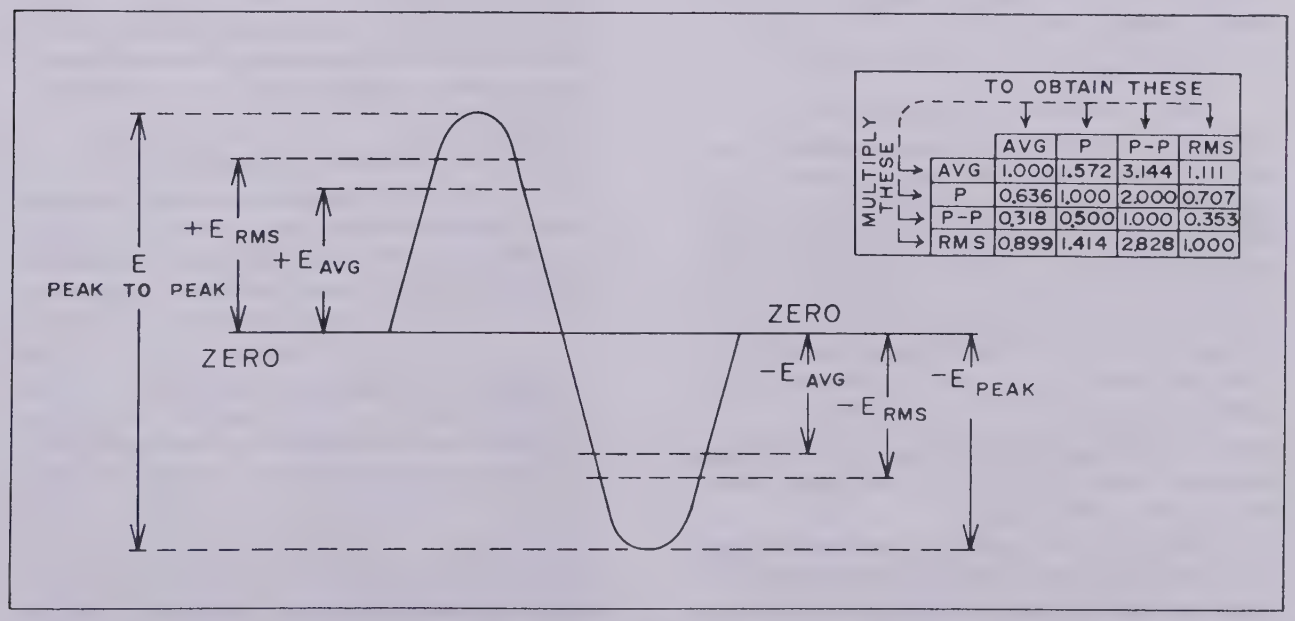


Figure 3–2. Average, RMS, and Peak Voltage Relationships of a Sine Wave

The total input impedance of the DMM may be calculated as follows:

$$Z \text{ input} = \frac{R_{in}}{\sqrt{1 + (2\pi F \times R_{in} \times C_{in})^2}}$$

Input Resistance = R_{in} = 10 Megohms = $10 \times 10^6 \Omega$

Input Shunt Capacitance = C_{in} + C leads

Frequency = F = in Hz.

As an example at 60 Hz

$$Z_{in} = 8.72 \text{ Megohms}$$

Measurement error caused by a high source impedance (Z_s) may be calculated as follows:

$$\% \text{ measurement error} = 100 \times \frac{Z_s}{Z_{in} = Z_s}$$

As an example, the error of measurement at 60 Hz from a test point having 100,000 ohms source impedance (Z_s) using the DMM Z is calculated above.

% error =

$$= 100 \times \frac{100{,}000}{8{,}720{,}000 + 100{,}000} = \frac{100{,}000}{8{,}820{,}000}$$

$$= 1.13\%$$

d. In addition, ac current (I) will flow in the leads causing additional measurement errors. In the above example, at 10 kHz, a 10-volt signal (E) will cause

$$I = \frac{E}{X_C} = \frac{10 \text{ V}}{160{,}000 \ \Omega} = 62.5 \ \mu A$$

to flow through the test leads and the input circuitry of the DMM.

e. The ac voltage or current to be measured may be "off ground." The multimeter must reject the off ground ac or dc "common mode" voltage. The rejection for common mode voltage is:

>100 dB at dc	(>100,000 to 1)
>60 dB at 60 Hz	(>1000 to 1)

When making ac measurements, use the COMMON input connector as the "low potential" point to system ground (earth). This minimizes the common mode signal errors. Determine if the multimeter reads ac voltages when the test leads are shorted together and tied to the "high" side of the AC signal to be measured. If a reading of some magnitude is then displayed on the multimeter, try to minimize the amplitude of the voltage between case and COMMON. Always limit the common mode voltage to 1200 volts peak.

3–41. Overvoltage Indication. A flashing display indicates overvoltage (overload). Switch to the next higher range until a steady display appears.

3–42. Overrange. The DMM may be used to 100% overrange on the AC mode to the limits of 1200 volts rms sinusoidal (1680 volts peak) and 2 amperes rms sinusoidal. A reading of 1000 represents full range and 1999 is considered full scale. The display will flash above 100% overrange when full scale (1999) is exceeded.

3–43. Frequency range is usable from 15 Hz to beyond 110 kHz for both ac current and ac voltage measurements. The instrument is specified with calibration over the range of 50 Hz to 50 kHz.

3–44. Display zero is automatically adjusted. To check zero simply short the V–Ω to COMMON input connectors with a direct buss wire strap. The display will read zero to 8 counts on all ac ranges. The additional counts beyond zero represent circuit noise seen by the wideband AC to DC converter. This noise adds to the signal as

$$V \text{ display} = \sqrt{(V \text{ input})^2 + (V \text{ noise})^2}$$

Noise contribution to measurement error therefore becomes insignificant for display readings above 0100 (5% of full scale).

An example, 5 digits of DMM noise and 50 digits of signal give a display reading of

$$V \text{ display} = \sqrt{(50)^2 + (5)^2} = \sqrt{2{,}525} = 50.25$$

which will display as 50

3–45. AC Current.

3–46. See Table 3–2 for ac current operation limits.

3–47. To select ac current

a. Depress the mA (S4) pushbutton.

b. Depress the AC/DC pushbutton (S2) in to select AC.

c. Depress the 1000 (S11) pushbutton.

3–48. Connect the input signal to the A and COMMON (LO) input connectors.

3–49. Select range by first depressing the 1000 (S11) pushbutton and then progressively increasing DMM sensitivity until the display shows 3 or 4 significant digits of information.

3–50. AC Current Measurement Precautions.

a. Do not exceed 2 amperes on any range. The circuit breaker will protect the mA range on overloads above 2 A. To RESET the circuit breaker, allow 10 seconds and push the button above the A binding post input connector.

WARNING

Do not exceed 15 amperes peak input.

b. Do not float the ammeter (ac current meter) COMMON input binding post more than 1200 volts peak above ground.

c. The dc mA input is protected for overvoltage by clipping diodes which clamp at ±200 mV. The protective circuit breaker will trip whenever these diodes clamp and the resultant overload current exceeds 2 amperes.

d. The shunt resistors which meter current in the DMM vary with range. See the specification table in Section 1 for shunt resistance for each range. A measurement error will occur if the source resistance (R_s) is not at least 1000 times greater than the shunt resistance (R_r) of the DMM.

$$\% \text{ error} = \frac{100 \times R_r}{R_s + R_r}$$

For example, on the 1 mA range where the shunt resistance (R_r) is 100 ohms, a source resistance (R_s) of 10,000 ohms will result in an ac mA measuring error of 1% of reading.

e. AC currents are often highly distorted yet the Ballantine 3028A improves accuracy since the instrument responds to the ac rms value of the input current. Refer to paragraphs 3–35 and 3–36 and the specifications in Section 1 for additional details.

f. The DMM is almost always floated above earth ground when making current measurements. See paragraph 3–17(d) for a description of measurement errors caused by common mode signals. In typical use, the DMM will read ±10 counts of error when 100 volts peak of common mode signal is present. For common mode error calculations on the ac mA ranges always use the most sensitive ac voltage range (100 mV), since the voltage developed across the DMM shunts is 100 millivolts full range.

g. The A to COMMON input connector resistance in the ac mA mode is listed in the specifications. The connector-to-connector resistance is greater than the shunt resistance due to the internal connecting leads. Always consider the connector-to-connector voltage drop when making precision current measurements.

3–51. Overcurrent Indication. A flashing display indicates overload. Switch to the next higher range until a steady display appears.

CAUTION

Do not switch the current range switches when currents exceed 100 mA. This will extend the life of the pushbutton switches.

3–52. The DMM may be used to 200% overrange on all ac mA ranges to 1999 mA (2 amperes). The display will flash above 100% overrange when full scale (1999) is exceeded.

3–53. The display zero is automatically adjusted. To check zero in ac mA mode short the A and COMMON input connectors with a short strap and the display will read 000 to 008. The residual counts are due to wideband ac circuit noise. See paragraph 3–44 for discussion of its minimal effects on ac measurement accuracy.

3–54. Currents in excess of 1999 mA may be measured using the Ballantine Model 606 Shunt. This shunt incorporates a 0.01-ohm resistor so that currents to ±20 amperes may be measured using the 100 mV ac range. The 3028A Option 21 is also available and it incorporates a 10-ampere current range.

3–55. RESISTANCE MEASUREMENTS.

3–56. **General.** The 3028A measures resistance from 0.1 Ω to 20 MΩ. The display is read directly in ohms, kilohms (kΩ) or megohms (MΩ). The 3028A features both a LO ohms and a HI ohms resistance mode.

3–57. LO ohms may be used for resistance measurements which demand low voltage across and low power dissipation in the resistance to be measured. The LO ohms is advantageous when measuring in circuit resistances in circuits using seven semiconductors. Diodes, transistors and other semiconductor junctions are not caused to conduct in the LO ohms mode since the voltage impressed across the unknown resistance is 90 mV at full range and only 180 mV at full scale. See Table 3–2 for LO ohms operating specifications.

3–58. The HI ohms mode is used for checking higher resistances to 20 megohms and for testing semiconductor junctions. The voltage impressed across the unknown resistance is 900 mV at full range and 180 mV at full scale. This is sufficient to test conduction of diodes and transistors as well as to minimize the effects of leakage. See Table 3–2 for HI ohms operating specifications.

3–59. To select LO ohms

a. Depress the LO Ω pushbutton (S6)

b. Depress the 100 range pushbutton (S7)

3–60. Connect the resistance to be measured across the V–Ω and COMMON input connectors.

3 -61. Select range by first depressing the 100 pushbutton (S7) and then progressively increasing the resistance range until the display shows 3 or 4 significant digits of information.

3–62. LO Ohms Measurement Precautions.

a. Do not apply voltage to the input terminals when using LO ohms mode or the reading will be in error.

b. Short the input test leads before making a measurement. Note the zero offset due to test lead and internal resistance of the DMM (typically less than 0.4 ohm). Subtract this "measured zero" reading from the actual measurement to obtain the most precise resistance measurement.

c. Do not exceed 285 V rms (sinusoidal) to the input terminals on the 100 range or more than 500 V rms (sinusoidal) to prevent overload damage.

CAUTION

Take care when making in-circuit resistance measurements which may have high voltages on capacitors or where power line voltage is present.

d. Avoid the LO ohms 1000 k range since its accuracy is affected by leakage in high humidity environments.

e. The LO ohms mode is not applicable to the 10 MΩ range and the display will flash if this range is inadvertently selected.

3–63. To Select HI Ohms

a. Depress the HI ohms pushbutton (S5).

b. Depress the 1 K range pushbutton (S8).

3–64. Connect the resistance to be measured across the V–Ω and COMMON input connectors.

3–65. Select range by first depressing the 1 K pushbutton (S8) and then progressively increasing the resistance range until the display shows 3 or 4 digits of significant information.

Note

The 100 range (S7) is not operative in the HIΩ mode and the display will flash should this range be inadvertently selected.

3–66. HI Ohms Measurement Precautions.

a. Do not apply voltage to the input terminals when using HI ohms mode or the reading will be in error.

b. Short the input test leads before making a measurement. Note that zero offset due to test lead and internal resistance of the DMM (typically less than 0.4 ohm). Subtract this "measured zero" reading from the actual measurement to obtain the most precise resistance measurement.

c. Do not exceed 285 V rms (sinusoidal) to the input terminals on the 100 range or more than 500 V rms (sinusoidal) to prevent overload damage.

CAUTION

Take care when making in-circuit resistance measurements which may have high voltages on capacitors or where power line voltage is present.

3–67. Overrange Indication. A flashing display indicates too high resistance for the range selected. Switch to next lower range until a steady display appears.

3–68. The DMM may be used to 200% overrange on all ohms ranges to a limit of 2 megohms in LO ohms and 20 megohms in the HI ohms mode. The display will flash above 100% overrange when full scale (1999) is exceeded.

3–69. The display zero is automatically adjusted. To check zero short the test leads connected to the V–Ω and COMMON input connectors together. Note the reading which should typically be limited to 001 to 010 by keeping the test leads short and the low resistance. Note the "actual zero" and subtract this offset from the actual reading to obtain the most precise resistance measurements.

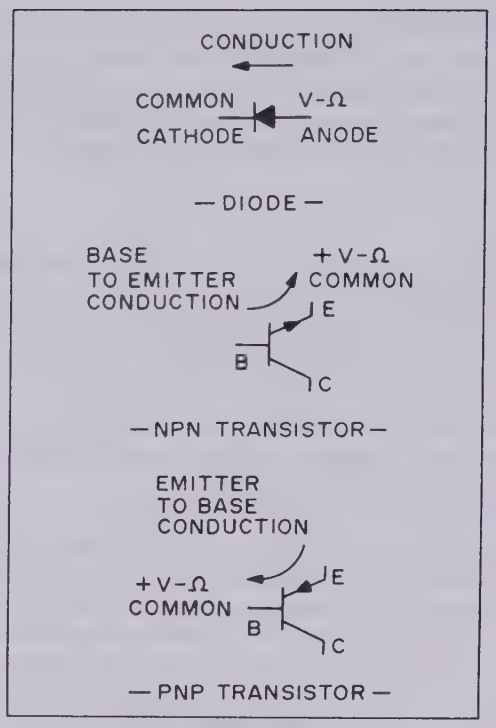


Figure 3–3. Transistor and Diode Testing

3–70. Testing Semiconductor Junctions.

3–71. The 3028A may be used to test transistors, diodes, and integrated circuits to determine the condition of the semiconductor junction. The V–Ω input connector is positive in respect to the COMMON connector and connections should be made as shown in Figure 3–3 to cause forward conduction.

3–72. The voltage applied to semiconductor junctions must be sufficient to cause conduction in the forward direction. The HIΩ mode provides a voltage to 2 volts and a maximum current of 1 mA (1 kΩ range) which is sufficient to cause forward conduction.

Note

Tests on silicon diodes and power transistors should be performed using the HIΩ 1k range to permit maximum current to flow. Higher resistance ranges generally have too low a measuring current to properly test forward conduction of the junction.

3–73. To test a transistor or diode, first identify the leads as given on the schematic or the manufacturer's data sheet. To determine the condition of a transistor, a measurement of base-emitter and base-collector junctions is required. See Table 3–3 for test conditions for silicon NPN and PNP transistors.

TABLE 3–3. TEST CONDITIONS FOR SILICON TRANSISTORS

Transistor	Connector		DMM		Normal Indication	Faulty Indication
	COMMON (–)	V–Ω (+)	Function	Range		
NPN	Emitter	Base	HIΩ	1K	≈700 Ω	>1000 Ω <400 Ω
NPN	Base	Emitter	HIΩ	10M	>20 MΩ (flashing)	<20 MΩ
NPN	Base	Collector	HIΩ	10M	>20 MΩ (flashing)	<20 MΩ
NPN	Collector	Base	HIΩ	1K	≈700 Ω	>1000 Ω <400 Ω
PNP	Base	Emitter	HIΩ	1K	≈700 Ω	>1000 Ω <200 Ω
PNP	Emitter	Base	HIΩ	10M	>20 MΩ (flashing)	<20 MΩ
PNP	Collector	Base	HIΩ	10M	>20 MΩ (flashing)	<20 MΩ
PNP	Base	Collector	HIΩ	1K	≈700 Ω	>1000 Ω <400 Ω

3–74. In-Circuit Measurement of Resistance.

3–75. In-circuit resistances may be measured with the Model 3028A using the LOΩ mode. LOΩ has a maximum voltage of 180 mV full scale which is generally insufficient to obtain conduction in transistor and semiconductor diode junctions.

3–76. In-Circuit Resistance Measurement Precautions.

a. Always turn off all power on the circuit under test and wait sufficient time to discharge all capacitors which may retain a voltage which can damage the ohmmeter (>285 volts rms) or cause measurement errors.

b. Check the schematic of the circuit under test to be certain that the component to be measured is not shunted by others which will cause apparent measurement errors and confusion.

c. When checking sensitive components such as detector diode junctions, minimize ohmmeter measuring current by selecting a higher resistance range (such as 10k where maximum measuring current is 180 micramperes). Since measuring current is directly proportional to measuring voltage, it is recommended that downscale (<300) measurements be used to minimize ohmmeter power impressed on the device under test.

As an added precaution, short the ohmmeter test leads BEFORE and while initially applying them to the sensitive circuit component under test so that the initial ohmmeter measurement potential is zero. Then release the short and make the resistance measurement. Use of this technique never lets the measuring potential exceed the voltage at which the final resistance measurement is made.

3–77. ACCESSORIES – OPTIONAL.

3–78. RF Probe Model 10850B.

3–79. The Ballantine 10850B probe is a peak detector probe which provides voltage measurement capabilities for sinewaves to beyond 700 MHz. It is a peak detector probe using a semiconductor diode. Maximum signal is 30 V ac and a blocking capacitor will hold off dc to 200 volts maximum.

CAUTION

Never exceed these maximum voltage ratings.

3–80. The 10850B is usable from 50 kHz to beyond 700 MHz. It can be calibrated at any frequency with the adjustment provided in the compensating box at the end of the cable. Normal use provides broadband flatness within

±0.5 dB to 200 MHz, ±1 dB at 270 MHz, and ±3 dB at 470 MHz. Do not use for signals less than 10 mV or below 50 kHz since the detector time constant is too short. The probe may be used as an AM detector if modulation frequencies are in the 50 Hz to 20 kHz range.

3–81. The 10850B is supplied with a ground lead as well as a BNC tip adapter. The ground lead inductance will cause substantial measurement accuracy errors above 10 MHz and the BNC adapter must always be used when calibrating or measuring higher frequency signals.

3–82. The probe may be calibrated by adjusting the trimmer potentiometer in the termination housing on the 1-volt or 10-volt ranges from any known precision ac source within its frequency range. Always use the 10850B RF probe on the 100 mV, 1 V, and 10 V ranges of the 3028A DMM. The calibrating reference frequency is 10 MHz although any frequency from 1 MHz to 200 MHz may be used as the set point.

3–83. High Voltage DC Probe Model 10800B.*

3–84. The Ballantine 10800B high voltage probe is used to divide high dc voltages so they may be measured by the DMM. Division ratio is 1000 to 1 and is adjustable by ±10% to permit precise calibration of the division ratio of the probe to the multimeter.

3–85. Maximum probe voltage rating is ±40 kV dc. At no time should the 40 kV peak rating be exceeded.

WARNING

ALWAYS CONNECT THE GROUND LEAD TO THE CIRCUIT UNDER TEST BEFORE CONNECTING THE HV PROBE. FAILURE TO OBSERVE THIS PRECAUTION WILL APPLY FULL HIGH VOLTAGE TO THE INSTRUMENT AND MAY NOT ONLY RESULT IN INSTRUMENT DAMAGE BUT MAY CAUSE A SERIOUS PERSONNEL HAZARD. ALWAYS CONNECT THE GROUND LEAD FIRST AND PERMANENTLY WHEN USING THE HIGH VOLTAGE PROBE. HANDLE THE PROBE ONLY AT ITS BLACK HANDLE AND AVOID CONTACT WITH THE FLASH GUARD AND TIP AREA.

*For operator safety, when using high-voltage probes such as the 10800B and 1301B, permanently connect a 3.3 MΩ, 1/2 W resistor (P/N 12129340A) from the power line to earth ground, and a 47 MΩ, 1 W resistor (P/N 12129350A) from COMMON to earth ground.

3–86. The accuracy of the probe is ±1% plus the accuracy of the DMM. A voltage coefficient of 0.0002% (2 ppm) per volt to 10 kV, 0.0003% (3 ppm) per volt to 20 kV, and 0.0005% (5 ppm) per volt to 40 kV is additionally applicable. The probe is calibrated at 1 kV or 10 kV dc with the potentiometer located in the terminating box.

3–87. The probe ground is always connected to the COMMON input connector. Set the DMM to DC and V. Use the 1 V, 10 V and 100 V ranges of the multimeter and read directly to 1.999 kV on the 1 V ranges, 19.99 kV on the 10 V range and 40.00 kV on the 100 V range.

3–88. High Voltage AC Probe Model 1301B.*

3–89. The 1301B High Voltage AC Attenuator Probe is used for measurements up to 10,000 volts rms (sinusoidal); or 14 kV peak. The probe is a capacitive divider with a division ration of 1000 to 1 (60 dB). Although the 1301B has a usable frequency response from 10 Hz to 10 MHz it is usable with the 3028A ac volts measuring mode to provide high voltage measurements from <40 Hz to beyond 100 kHz.

3–90. To use the 1301B Probe, switch to AC and V. Set range to 100 mV, 1 volt, or 10 volts to read 199.9 V, 1.999 kV, or 10 kV rms, respectively.

WARNING

ALWAYS CONNECT THE GROUND LEAD TO THE CIRCUIT UNDER TEST BEFORE CONNECTING THE HV PROBE. FAILURE TO OBSERVE THIS PRECAUTION WILL APPLY FULL HIGH VOLTAGE TO THE INSTRUMENT AND MAY NOT ONLY RESULT IN INSTRUMENT DAMAGE BUT MAY CAUSE A SERIOUS PERSONNEL HAZARD. ALWAYS CONNECT THE GROUND LEAD FIRST AND PERMANENTLY WHEN USING THE HIGH VOLTAGE PROBE. HANDLE THE PROBE ONLY AT ITS HANDLE AND AVOID CONTACT WITH THE FLASH GUARD AND TIP AREA.

3–91. To calibrate the 1301B probe, simply unscrew the probe tip to provide access to the calibration adjustment screw. Connect the probe to the V–Ω and COMMON connectors and set the DMM to AC and V. Set range to 1 V. Apply 1 kV at 1 kHz to the probe from a voltage calibrator such as the Ballantine 421A. Adjust the probe calibration until the 3028A reads 1.000 ±3 digits.

SECTION 4
THEORY OF OPERATION

4–1. INTRODUCTION.

4–2. This section of the manual contains a description of the circuitry used in the 3028A. Figure 4–1 is a simplified block diagram of the instrument. Basically, the diagram can be broken down into eight functional areas. These are input voltage divider, current shunts, ohms converter, ac (volts to mA) converter circuit, active filter, dc analog-to-digital converter, digital display section, and the power supply.

4–3. CIRCUIT DESCRIPTION.

4–4. A complete schematic is given at the rear of this manual. Refer to this schematic diagram throughout the following circuit description.

4–5. Input Voltage Divider (Reference Designator 100 Series).

4–6. A ten-megohm series connected resistor set is tapped to provide division ratios of 1, 100 and 1000 to 1. Resistors R100 and trimmer potentiometer R101 set the 100 to 1 tap. Resistors R102 and R103 set the 1000 to 1 tap. Resistor R104 is the basic high stability calibration resistor in the input attenuator and is the resistive reference for the ohmmeter. The 100 mV and 1 V ranges use the 1 to 1 tap. The 10- and 100-volt ranges use the 100 to 1 tap and the 1000-volt range uses the 1000 to 1 tap.

4–7. Trimmer capacitors are connected across the input voltage divider to maintain a constant attenuation ratio over the frequency band when the input voltage divider is used for ac voltages. High frequency response compensation may be adjusted during calibration with trimmer capacitor C103 for the 1000 to 1 range and with C110 for the 100 to 1 range when attenuator components are replaced.

4–8. Current Shunts (Reference Designator 200 Series).

4–9. Current shunts consist of four two-terminal and two four-terminal stable noninductive wirewound resistors enclosed in RN200, a dual in-line resistor package. These series-connected resistors are selected depending on the ac or dc current range selected. Resistors of 1000, 100, 10, 1 and 0.1 ohm correspond to 100 μA, 1 mA, 10 mA, 100 mA and 1000 mA ranges respectively. The four-terminal resistor ensures accurate current measurements with variations in lead resistance and components. The input COMMON connections are completed through the resistor network to the analog circuit ground of the DMM.

4–10. The voltage required across any shunt for a display reading of 1000 is 100 mV and the maximum voltage is 200 mV at full scale. The shunts are protected against overvoltage by power diodes CR200 through CR203. Current overload protection above 2 A is provided by quick acting thermal circuit breaker CB10.

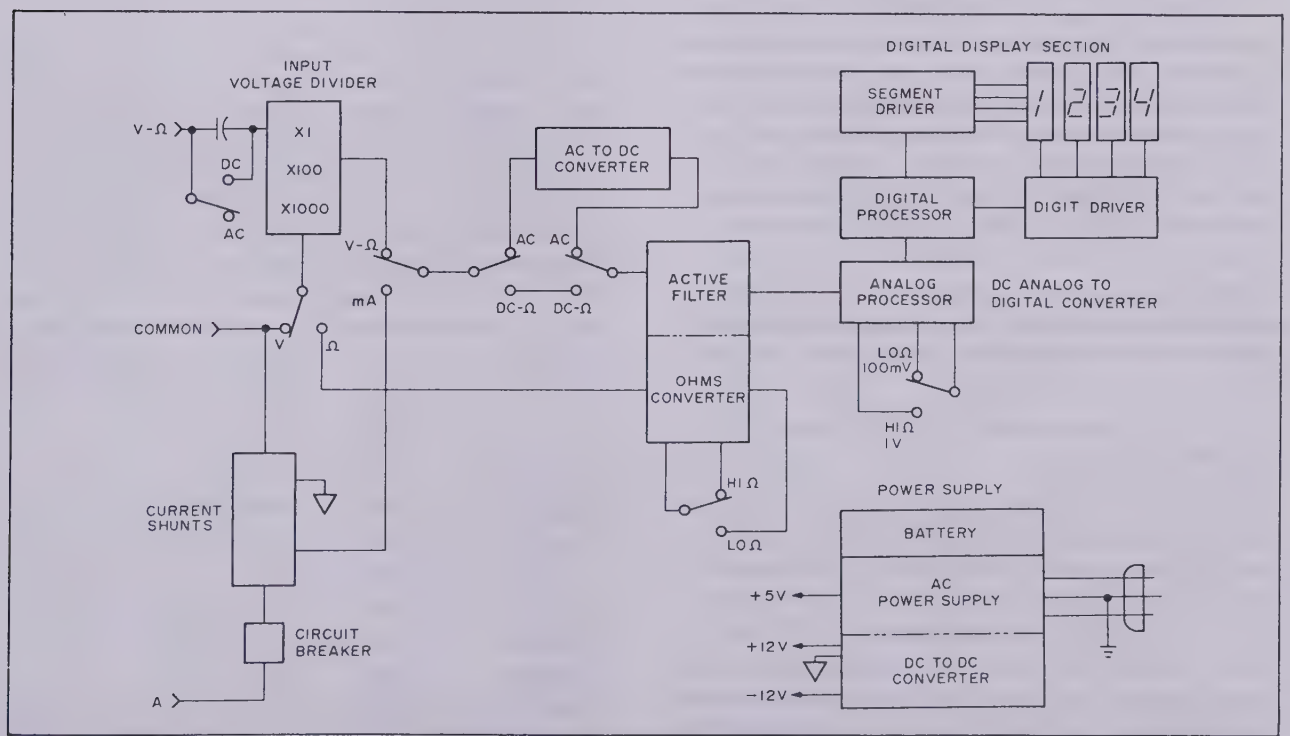


Figure 4–1. Model 3028A, Block Diagram

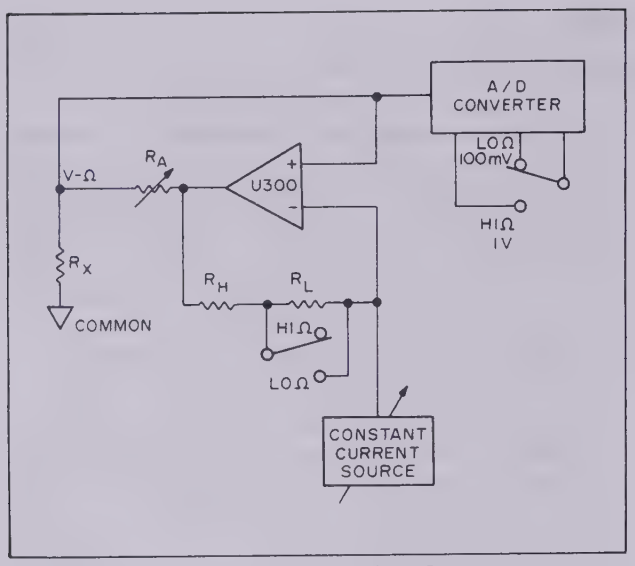


Figure 4–2. Simplified Ohms Converter

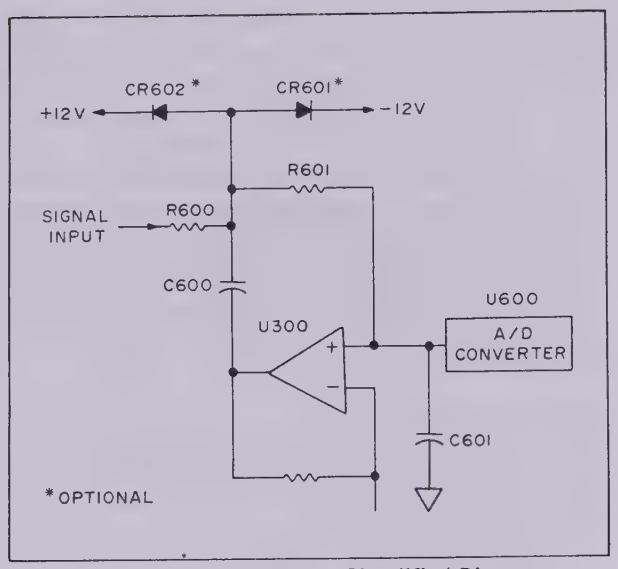


Figure 4–3. Active Filter, Simplified Diagram

4–11. Ohms Converter (Reference Designator 300 Series).

4–12. The ohms converter provides a constant current through the unknown resistance to be measured (R_X). This current creates a voltage drop across R_X which is then measured by the dc analog voltage to digital converter. See Figure 4–2 for a simplified diagram.

4–13. FET input operational amplifier U300 bootstraps the current source comprised of Q300, Q301 and Q302. Q301 is diode-connected to temperature compensate Q300 while Q302 acts as the voltage reference. Constant current level is set by R303 and R304 in the emitter return of Q300. R_A is the input voltage divider, resistors R100 through R104, switched for ohmmeter ranging. With the non-inverting input of U300 connected to the junction of R_A and R_X, current is caused to flow through R_A and R_X. The inverting input of U300 is used to stabilize the voltage and gain across U300 by making the constant current flow through feedback resistors R_H and R_L.

4–14. For a given range and HIΩ or LOΩ mode a constant voltage is maintained across R_A. If R_X is within the range selected, the voltage developed will be directly proportional to R_X.

4–15. The constant voltage across R_A is maintained as indicated in Table 4–1.

4–16. The HIΩ mode requires 1.8 V across R_X at a full scale reading of 1999. In this mode R_H plus R_L are 10 kΩ and provide negative feedback across U300. The sensitivity of the dc analog voltage to digital converter is now set to 1 V. The HIΩ mode is not operative on the 100 range.

4–17. Ohms overload protection is provided by the current limiting of the 7-watt, 10 kΩ input voltage divider resistor R104 and Zener diodes CR300 and CR301 which limit the voltage excursion at the output of U300 to ± 10 volts. The dc analog voltage to digital converter is protected against overvoltage by R600, R601, and limiting diodes within U300.

4–18. The dc analog voltage to digital converter has its basic sensitivity increased for a full scale reading of 1999 whenever 1800 is applied in either ohms mode. Gain switching is accomplished by S5F and S6C which insert a 28.7 kΩ resistor from RN600 into the feedback chain. This minimizes the maximum LOΩ measuring voltage to 180 mV.

4–19. Active Filter.

4–20. The active filter is a two-pole, low-pass filter which rejects ac signals and passes only dc voltages to the dc analog voltage to digital converter. A cutoff frequency (−3 dB) of 8 Hz and a rejection ratio of 38 dB at 60 Hz are provided by this filter. The active filter also prevents overloading of the converter input when large ac voltages are superimposed on the dc voltage to be measured.

TABLE 4–1.

Range	Mode	R_A	Volts across R_A
100	LOΩ	10 kΩ	10
1 kΩ	LOΩ	10 kΩ	1
10 kΩ	LOΩ	100 kΩ	1
100 kΩ	LOΩ	10 MΩ	10
1000 kΩ	LOΩ	10 MΩ	1
1 kΩ	HIΩ	10 kΩ	10
10 kΩ	HIΩ	100 kΩ	10
100 kΩ	HIΩ	100 kΩ	1
1000 kΩ	HIΩ	10 MΩ	10
1 MΩ	HIΩ	10 MΩ	1

4–21. Operational amplifier U300 is used for the active filter as well as the Ohms converter. Its non-inverting input senses the signal at the input of the converter and feeds it through C600 to the junction of R600 and R601. In effect, it multiplies the resistance of R601 at high frequencies and therefore provides a larger effective time constant for the low-pass filter comprised of R600, R601 and C601. See Figure 4–3 for a simplified diagram of the active filter. Optional diodes CR601 and CR602 provide high peak overload protection for U300 and U600 by limiting at ± 12 V.

4–22. AC to DC Converter (Reference Designator 400 Series).

4–23. The ac to dc converter takes the ac input signal from the input voltage divider or the current shunts and converts it into a dc voltage. This dc voltage is then measured by the dc voltage analog to digital converter. The ac to dc converter is a wideband circuit operating from <15 Hz to beyond 250 kHz and over a dynamic range of 100 μV to beyond 2 volts rms. See Figure 4–4 for a simplified diagram of the ac converter.

4–24. The input to the ac converter consists of field effect transistor Q400. This dual gate MOSFET is connected with PNP Q401 to provide high input impedance and low output impedance. It has internal diode protection for input overloads. Resistor R400 is the voltage dropping resistor which limits the FET input current to avoid damage during overloads.

4–25. The input FET follower (Q400) and transistor (Q401) drive the noninverting input of operational amplifier Q400. Diodes CR400 and CR401 protect the input of U400 from overloads. Feedback from the output of U400 to its inverting input causes the operational amplifier output to follow the input signal from FET follower Q400. This results in a current flow from ground through R408 plus R409 which is equal to $E_{in}/(R408 + R409)$. Diodes CR402 and CR403 conduct on alternate cycles of the input ac waveform. Therefore, one-half the average current flows through R406. The ac to dc converter is an operational full wave rectifier and the voltage at the junction of CR403 and R406 is sent through low pass filter R411 and C410 for measurement by the dc analog voltage to ac converter. The converter responds to the average of the ac signal input and is calibrated in rms of a sinewave. U500 is a high performance operational amplifier which in conjunction with CR500 and C501 forms a positive peak detector. The peak value of the input signal is stored in C501 and added to the output from the average responding detector through R504. R411 and R504 are chosen to give optimum rms response at a crest factor of 1.41 ± 20%.

4–26. The input to the ac converter is either 200 mV or 2 V full scale. The circuit is designed to operate over this two decade dynamic range without changing gain. AC conversion gain is adjusted to unity for all conditions by R409. Crest factor ratio is set by R411 and R504.

4–27. DC Analog Voltage to Digital Converter (Reference Designator 600 Series).

4 28. The dc input voltage is coupled to the analog processor U600 via the precision input voltage divider and a two-pole active low-pass filter. The input voltage to the processor is limited by internal voltage limiters and protective diodes in U300. Ranging resistors in the input voltage divider are selected by the front panel RANGE switches to provide a 100-millivolt voltage for the 100 mV and 10 volt ranges and 1 volt for all other ranges.

4–29. The monolithic analog processor contains a bipolar comparator, a bipolar integrating amplifier, two MOSFET input amplifiers, several analog switches and the necessary level shifting drivers to allow the analog and digital processors to be directly interfaced.

4–30. The precision voltage reference Q601 is temperature compensated and supplied by constant current sources Q600.

4–31. The feedback resistors which set gain in the analog processor are housed in resistor network RN600 for optimum temperature stability. R604 provides coarse calibration adjustment over the voltage limits reference Q601. R608 is the 100 mV range calibration adjust. R607 serves as the 1 V calibration adjust.

4–32. Input offset current compensation is provided by shifting the reference ground level at the input of the analog

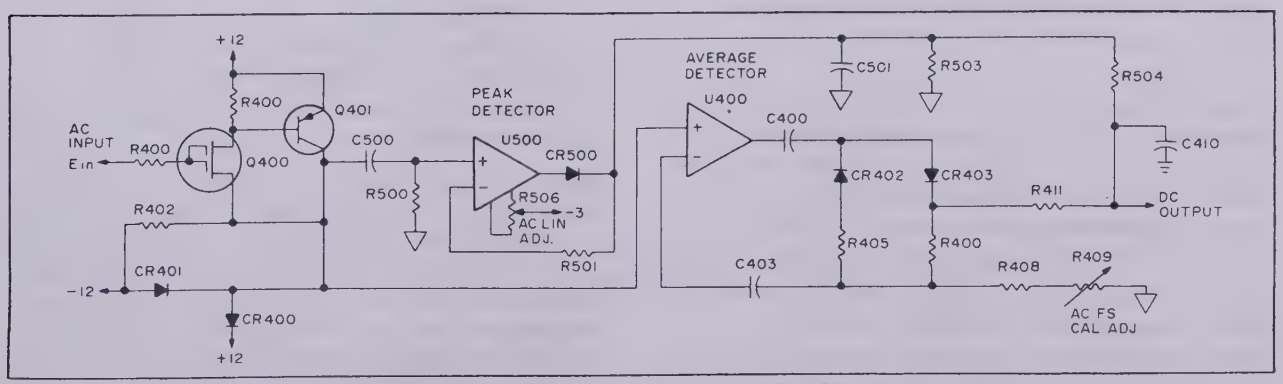


Figure 4–4. AC Converter, Simplified Diagram

processor U600. R605 provides offset compensation for a compromise of optimum polarity turnover and display zero adjust.

4–33. A measurement cycle consists of two phases: the measure interval and the auto-zero interval. In the measure interval, a conversion technique balances the charge supplied by a current proportional to the input voltage. The accumulation of quantized charges is measured and read as a digital number in BCD format. The units of quantized charge are provided through pulse width modulation of a reference current.

4–34. The auto-zero interval allows the effect of offset, temperatures, and drift to be impressed on the auto-zero storage voltage, which is maintained as a reference by the capacitor C602. Therefore, during the succeeding measure interval, these effects will be balanced out. The input of the buffer amplifier is grounded during this interval.

4–35. Digital Display Circuits (Reference Designator 700 Series).

4–36. The digital processor U700 derives its inputs from analog processor U600 and provides segment control and digit strobing of the multiplexed display. The digital processor combines the counting, storage, and data multiplexing functions with the logic necessary to control the analog processor. Output buffers provide the polarity sign, digit strobe and multiplexed BCD data outputs. The digit scan is an interlaced format of digits 1, 3, 2, and 4.

4–37. The digital processor has a built-in overrange flashing circuit. The presence of a count of 2000 or greater in the BCD counter causes the 3½ digit display to blink off during the zero cycle resulting in a flash rate equal to the sampling rate of four readings per second.

4–38. Decoder driver U702 translates the BCD information from the digital processor to drive the anodes of LED numeric readouts SD750, 751 and 752. The common cathodes of these LEDs are strobed by the digital processor U700 which acts as a current sink. DS750 is the least significant digit (LSD).

4–39. The display is tested by illuminating all seven segments in each numeric. Display test is activated by simultaneously pushing the V and MA pushbuttons S3 and S4. U701 then inverts this signal and activates the test mode in U702.

4–40. The numeric "1" is formed by two segments in common anode LED DS753 which also includes the polarity sign. The "1" segments are driven from U701. The polarity plus symbol is controlled by Q700 and pushbutton switch S2 which illuminates the polarity sign only in the DC modes. Q701 strobes DS753 on command from U700.

4–41. Decimal point illumination automatically controlled by the range pushbutton switches S7 thru S12.

4–42. The clock signal for the analog and digital processor is generated by the dc-to-dc power converter in the power supply. For optimum normal mode rejection in the analog processor the clock frequency must be a direct multiple of the power line frequency. For 60 Hz power line the clock is set to 24.576 kHz and 25.6 kHz for 50 Hz.

4–43. DC to DC Power Converter (Reference Designator 800 Series).

4–44. The dc to dc power converter transforms the +5 volt levels. Q800 and Q801 alternately switch step-up autotransformer T800. The switching frequency is adjustable with R800 and should be set as indicated above in paragraph 4–42. The square wave output from T800 is rectified by full-wave rectifier diodes CR801 and CR802 to provide +12 volts and CR800 and CR803 to provide −12 volts. Capacitors C803 and C804 act as output filters.

4–45. R800 couples the clock signal from the dc to dc power converter to digital processor U700.

4–46. AC Power Supply (Reference Designator 900 Series).

4–47. The ac power line is connected to T900 which transforms the line voltage to provide a 10-volt dc supply using bridge rectifier CR900 and filter capacitor C900.

4–48. Integrated circuit, three-terminal, 5-volt regulator U900 regulates the output from the bridge rectifier. All 5-volt circuits and the dc-to-dc power converter are supplied from U900.

4–49. Rechargeable Battery Supply (Optional).

4–50. The rechargeable battery power supply powers the DMM whenever line voltage is removed or drops below the minimum needed to drive regulator U900. Four nickel cadmium "C" cells are the battery power source.

4–51. The four batteries are wired in series to provide nominally 4.5 volts. Q900 acts as the battery cutout switch to guard against battery reversal and to automatically switch the batteries out of the circuit when ac power is available through U900. The battery output voltage is sufficiently stable during discharge so that the battery supply substitutes for regulator U900 in the +5 volt dc supply.

WARNING

USE ONLY NICKEL CADMIUM "C" CELLS TO POWER THE MODEL 3028A. USE OF ALKALINE OR CARBON ZINC CELLS MAY CAUSE DAMAGE AND VOID THE WARRANTY.

4–52. To charge the batteries, the POWER pushbutton S1 is set to OFF and ac power is applied. The higher voltage tap on T900 is then activated and the batteries are charged through DS900 and R902 by dc power from bridge rectifier CR900. The instrument is not operating when batteries are being charged. The nominal charging current of 200 mA is maintained throughout the charge cycle by the regulating characteristics of lamp DS900.

SECTION 5
MAINTENANCE AND CALIBRATION

5–1. INTRODUCTION.

5–2. This section contains information required to maintain the instrument within specifications. The following paragraphs detail:

a. Performance Assurance Checks.

b. Calibration Procedures.

c. Fault Finding (Troubleshooting) details.

d. Preventive Maintenance.

5–3. The instrument is designed with premium components. Like other Ballantine instruments, it will provide many years of satisfactory service. Ballantine recommends that performance assurance checks and preventive maintenance procedures be performed on the following schedule:

a. Routine laboratory service every 12 months or 1,000 hours of use whichever comes first.

b. Service in the field or in extended environments every six months or 450 hours of use whichever comes first.

5–4. Full NBS traceable calibration should be performed once each year. Normally the user will provide recalibration services in his plant. If required, Ballantine will gladly provide this calibration service at our Boonton, N. J. service center for a nominal charge.

5–5. REQUIRED TEST EQUIPMENT.

5–6. Table 5–1 provides a list of test equipment required to properly check, calibrate, and maintain the instrument. Equivalent test equipment meeting all the minimum requirements may be substituted if the recommended items are not available.

TABLE 5–1. REQUIRED TEST EQUIPMENT

Instrument Type	Purpose	Recommended Model	Specifications
DC Voltage Calibrator	DC Voltage Calibration	Fluke 332M	10 mV to 1100 V dc. Five-digit resolution. 0.03% accuracy.
AC Voltage Calibrator	AC Voltage Calibration	H-P 745A/746A	10 mV to 1100 V ac. 10 Hz to 110 kHz. Five-digit resolution. 0.05% accuracy.
DC Current Calibrator	DC Current Calibration	Fluke 382A or 760A	10 μA to 1 A dc. Five-digit resolution. 0.05% accuracy.
Resistance Standard	Ohmmeter Calibration	Shallcross 883	10Ω to 10 MΩ. ±0.1% accuracy. Decade dials.
AC/DC True RMS Voltmeter	Line Voltage Measurement	Ballantine 3620A	10 mV to 1 kV, dc and ac true rms. 0.25% accuracy. 4½-digit resolution. 1 μV resolution.
Digital Multimeter	Troubleshooting Tool	Ballantine 3028A	DC volts to 1.2 kV. AC volts to 1.2 kV. 20 Hz to 100 kHz. LOΩ, 100 to 2 MΩ. HIΩ, 1 kΩ to 20 MΩ. AC current to 2A. DC current to 2 A. 3½ digits.
Oscilloscope with probes	Troubleshooting Tool	Ballantine 1010B with 10601B probes	Dual Trace. 5 mV, dc to 10 MHz. 100 ns/cm to 1 sec/cm. 10:1 divider probes.
AC Current Source	AC Current Calibration	Fluke 760A	10 μA to 1 A, ac ±0.2% accuracy.
Line Control Variac	Set Line Voltage	General Radio W5MT3AW	0 V to 135 V (0 V to 270 V).
Frequency Counter	Set A to D Clock frequency	Ballantine 5725B or 5500B	6 digits. 10 Hz to 1 MHz.

TABLE 5–2. DC VOLTAGE ACCURACY CHECK

DC Voltage Calibrator Voltage	DMM		Readout Display Limits
	Range	Function	
0.0000	100 m	VDC	–00.1 to +00.1
+0.0100	100 m	VDC	+09.8 to +10.2
+0.1000	100 m	VDC	+99.8 to +100.2
–0.1000	100 m	VDC	–99.8 to –100.2
+0.1800	100 m	VDC	+179.7 to +180.3
+1.0000	1	VDC	+.998 to +1.002
+10.000	10	VDC	+9.98 to +10.02
+100.00	100	VDC	+99.8 to +100.2
+1000.0	1000	VDC	+998 to 1002

TABLE 5–3. DC CURRENT ACCURACY

DC Current Calibrator	DMM	
	Range	Readout Limits
00.0 μA	100 μ	–00.2 to +00.2
+100 μA	100 μ	+99.5 to +100.5
+1.000 mA	1 m	+.995 to +1.005
+10.00	10 m	+9.95 to +10.05
+100.0	100 m	+99.5 to +100.5
+1000	1000 m	+995 to +1006

TABLE 5–4. AC VOLTAGE ACCURACY

AC Voltage Calibrator		DMM	
Voltage	Frequency	Range	Display Limits
0000 mV	500 Hz	100 m	00.0 to 00.5
10.00 mV	500 Hz	100 m	09.7 to 10.3
100.00 mV	500 Hz	100 m	98.8 to 101.2
100.0 mV	5 kHz	100 m	98.8 to 101.2
100.0 mV	50 kHz	100 m	97.8 to 102.2
180 mV	500 Hz	100 m	178.1 to 182.0
180 mV	50 kHz	100 m	175.8 to 184.2
1.000 V	500 Hz	1	.988 to 1.012
1.000 V	5 kHz	1	.988 to 1.012
1.000 V	50 kHz	1	.978 to 1.022
10.00 V	500 Hz	10	9.88 to 10.12
10.00 V	50 kHz	10	9.78 to 10.22
100.0 V	500 Hz	100	98.8 to 101.2
100.0 V	50 kHz	100	97.8 to 102.2
1000.0 V	500 Hz	1000	988 to 1012
1000.0 V	50 kHz	1000	978 to 1022

5–7. PERFORMANCE ASSURANCE CHECKS.

5–8. The performance assurance checks are "in-cabinet" checks that compare the instrument with the applicable performance specifications. The sample performance test record, Form 5–1, may be used or duplicated to provide permanent performance test records. Beginning with incoming inspection checks, periodic performance assurance checks should be made in the sequence detailed below and before any attempt is made to calibrate the instrument. The performance assurance checks should also be used as part of the troubleshooting procedure and before returning the instrument to regular service after repair, recalibration, or extended storage. All checks are made at 23°C ±2°C and with COMMON connected to power line earth ground.

Note

Prior to making any of the following performance assurance checks set ac line voltage to 120 volts (or 100, 200, or 240 volts). If battery power is used, charge batteries at least 8 hours. Exercise each of the 12 pushbuttons several times to clean switch contacts by self-wiping action.

5–9. Power Supply and Display Check.

5–10. To check the power supply regulation and the display proceed as follows:

a. Connect the instrument to the ac power line through a Variac voltage control unit. Monitor ac voltage with the true rms responding ac voltmeter.

b. Set DMM pushbuttons as follows:

Mode	(S2)	AC
Function	(S4)	mA
Range	(S7)	100μ

c. Set line voltage to 120 ± 2 volts (or 100, 220 or 240 volts).

d. Depress POWER pushbutton switch S1 to "ON."

e. Observe that the digital display reads 00.0 to 00.3.

f. Depress V and mA pushbuttons S3 and S4 simultaneously.

g. Observe that the display reads 888 as an indication that the display performs satisfactorily.

h. Release V pushbutton S3 but depress mA pushbutton S4 to retain current function.

i. Lower line voltage to 102 V (or 87, 196 or 208 volts) and observe that the DMM display does not change. This checks low line voltage operation.

j. Raise line voltage to 130 volts (or 108, 245 or 260 volts) and observe that the DMM display does not change. This checks high line voltage operation. Reset line to 120 volts (100, 220 or 240 volts).

5–11. Battery Check.

Note

This battery check is required only when a rechargeable battery option, such as Option 05, is installed.

a. Continue as in Step 5–10(j) but disconnect ac power cable from the rear panel receptacle of the DMM. Connect earth ground to rear panel ground lug.

b. Observe that the batteries power the unit and that the display does not change.

c. Depress the "V" pushbutton S3. (This releases S4, the mA pushbutton.)

d. Depress the 1000 k and 10 M pushbuttons S11 and S12 simultaneously.

e. Observe that the display reads greater than 5.00 to indicate that the batteries are charged. Fully charged batteries will check at above 5.35.

5 -12. DC Voltage Accuracy Check.

5–13. To check the dc voltage accuracy of the instrument proceed as follows:

a. Set Mode pushbutton switch S2 to "DC."

b. Set function pushbutton switch S3 to "V."

c. Set POWER pushbutton switch S1 to "ON."

d. Depress range pushbutton switch S7 for 100 mV.

e. Connect a short across the V–Ω and COMMON input connectors.

f. Note a display reading of 0.00 ± 2 counts.

g. Remove the short from V–Ω and COMMON.

h. Connect the DC voltage calibrator positive output to the V–Ω input connector of the DMM and connect the negative calibrator output to the COMMON connector.

i. Proceed to check dc voltage accuracy at each setting of the voltage calibrator listed in Table 5–2. In each case the digital readout display of the DMM should be within the tolerance shown.

j. For negative readings reverse input leads at the DC voltage calibrator.

5–14. DC Current Accuracy Checks.

5–15. Set the DMM controls as follows:

a. Power (S1) ON

b. Mode (S2) DC

c. Function (S4) mA

d. Range (S11) 1000

5–16. Connect the mA input connector of the DMM to the positive output of the dc current calibrator and the COMMON input connector to the negative terminal of the current calibrator.

TABLE 5–5. OPTIONAL AC CURRENT ACCURACY CHECK

AC Current Calibrator		DMM	
Current	Frequency	Range	Display Limits
0000	500 Hz	100 μ	00.0 to 00.5
100.0 μA	500 Hz	100 μ	98.8 to 101.2
100.0 μA	50 kHz	100 μ	97.3 to 102.7
1.000 mA	500 Hz	1 m	.988 to 1.012
1.000 mA	50 kHz	1 m	.973 to 1.027
10.000 mA	500 Hz	10 m	9.88 to 10.12
10.000 mA	50 kHz	10 m	9.73 to 10.27
100.00 mA	500 Hz	100 m	98.8 to 101.2
100.00 mA	50 kHz	100 m	97.3 to 102.7
1000.0 mA	500 Hz	1000 m	973 to 1.027
1000.0 mA	1 kHz	1000 m	973 to 1.027

TABLE 5–6. RESISTANCE ACCURACY CHECKS

Resistance Standard	Function	DMM	
		Range	Display Limits
0000	LOΩ	100	00.0 to 00.6
100.00	LOΩ	100	99.4 to 100.6
1.0000 k	LOΩ	1 K	994 to 1006
1.0000 k	HIΩ	1 K	994 to 1006
10.000 k	LOΩ	10 K	9.94 to 10.06
10.000 k	HIΩ	10 K	9.94 to 10.06
100.00 k	LOΩ	100 K	99.4 to 100.6
100.00 k	HIΩ	100 K	99.4 to 100.6
1.000 M	LOΩ	1000 K	980 to 1020
1.000 M	HIΩ	1000 K	994 to 1006
1.000 M	HIΩ	10 M	9.79 to 10.21

TABLE 5–7. DC POWER SUPPLY LIMITS

Supply	Test Points	Voltage Limits
+5	TP5	+4.20 to 5.30
+12	TP9	+11.5 to +14.7
−12	TP7	−11.5 to +14.7

5–17. Check the accuracy at each setting of the dc current calibrator listed in Table 5–3. In each case the displayed readout must be within the tolerances shown.

5–18. AC Voltage Accuracy Checks.

5–19. Set the DMM controls as follows:

a. Power (S1) ON
b. Mode (S2) AC
c. Function (S3) V
d. Range (S11) 1000

5–20. Connect the ac voltage calibrator to the V–Ω and COMMON input connectors of the DMM.

5–21. Check the accuracy at each setting of voltage and frequency of the ac voltage calibrator as listed in Table 5–4. In each case the displayed readout must be within the tolerances shown.

5–22. AC Current Accuracy Checks.

5–23. AC current checks are optional. The current shunts within the instrument are used for both ac and dc. They are noninductive and have virtually no effect on frequency response which is determined by the ac to dc converter fully tested in paragraph 5–18 for ac voltage accuracy. Current accuracy is therefore checked for both ac and dc in paragraph 5–14. The following procedure is therefore given for reference only and need not be regularly performed. AC current accuracy checks are not required for the Performance Test Record Form 5–1.

5–24. Set DMM controls as follows:

a. Power (S1) ON
b. Mode (S2) AC
c. Function (S4) mA
d. Range (S11) 1000

5–25. Connect the ac current calibrator to the mA and COMMON input connectors of the DMM.

5–26. Check the accuracy at each setting of current and frequency of the ac current calibrator as listed in Table 5–5.

5–27. Ohms Ranges Accuracy Checks.

5–28. Set DMM Controls as follows:

a. Power (S1) ON
b. Function (S6) LOΩ
c. Range (S7) 100

5–29. Connect the Resistance Standard to the V–Ω and COMMON input connectors of the DMM.

5–30. Check the resistance accuracy of the HIΩ and LOΩ ranges of the DMM at each setting of the resistance standard listed in Table 5–6. In each case the displayed readout must be within the tolerances shown.

5–31. CALIBRATION PROCEDURES.

5–32. If any of the Performance Assurance checks show an out-of-tolerance condition, recalibration will be required. Table 5–1 lists the test equipment required to completely calibrate and certify the instrument. If the instrument cannot be properly adjusted refer to the troubleshooting and fault finding procedures detailed in paragraph 5–55.

Note

Only a qualified service technician with properly calibrated test equipment should service this instrument, since internal voltages may cause shock hazard. Calibrate at 23°C ± 2°C and connect COMMON to earth ground.

5–33. Removal of Covers. The top and bottom covers of the plastic enclosure are fastened together by four screws which are accessible through the bumper feet at the bottom cover. To remove the covers first disconnect ac power cord. Then remove the handle by pulling carefully and firmly on the handle detents until both sides of the handle snaps out of their second detent. Then remove the four screws and carefully pull the top cover up and out from the side sections. Take care not to misplace the four spacer sleeves used to space the top cover on the side supports. These spacers support the unit and provide electrical connections for the metallic coating shield on the top cover and side supports. Always remove NiCad batteries at this point if Option 05 is installed. The side sections may then be removed by pulling up from the bottom cover. The front and rear panels will now be free of support. The printed wiring board may be separated from the bottom cover by removing the retaining screws accessible at the top of the printed wiring board.

Note

When making final calibration always have the bottom cover, panels, and side supports installed with proper electrical interconnection to the metallic coating since it serves as a guard shield to minimize unwanted noise pickup.

5–34. Preliminary Inspection.

5–35. Always check the voltmeter for mechanical damage, loose parts, faulty solder joints, burned resistors, etc. Use a low wattage (25 watts) grounded soldering iron to make repairs and always replace components with exact equivalents to be certain that all performance specifications can be obtained. Use heat shunts when soldering diodes and semiconductors. Do not overhead circuit board printed wiring and pads.

5–36. Internal Adjustments and Test Points.

5–37. See Figure 5–1 for the location of internal adjustments and test points.

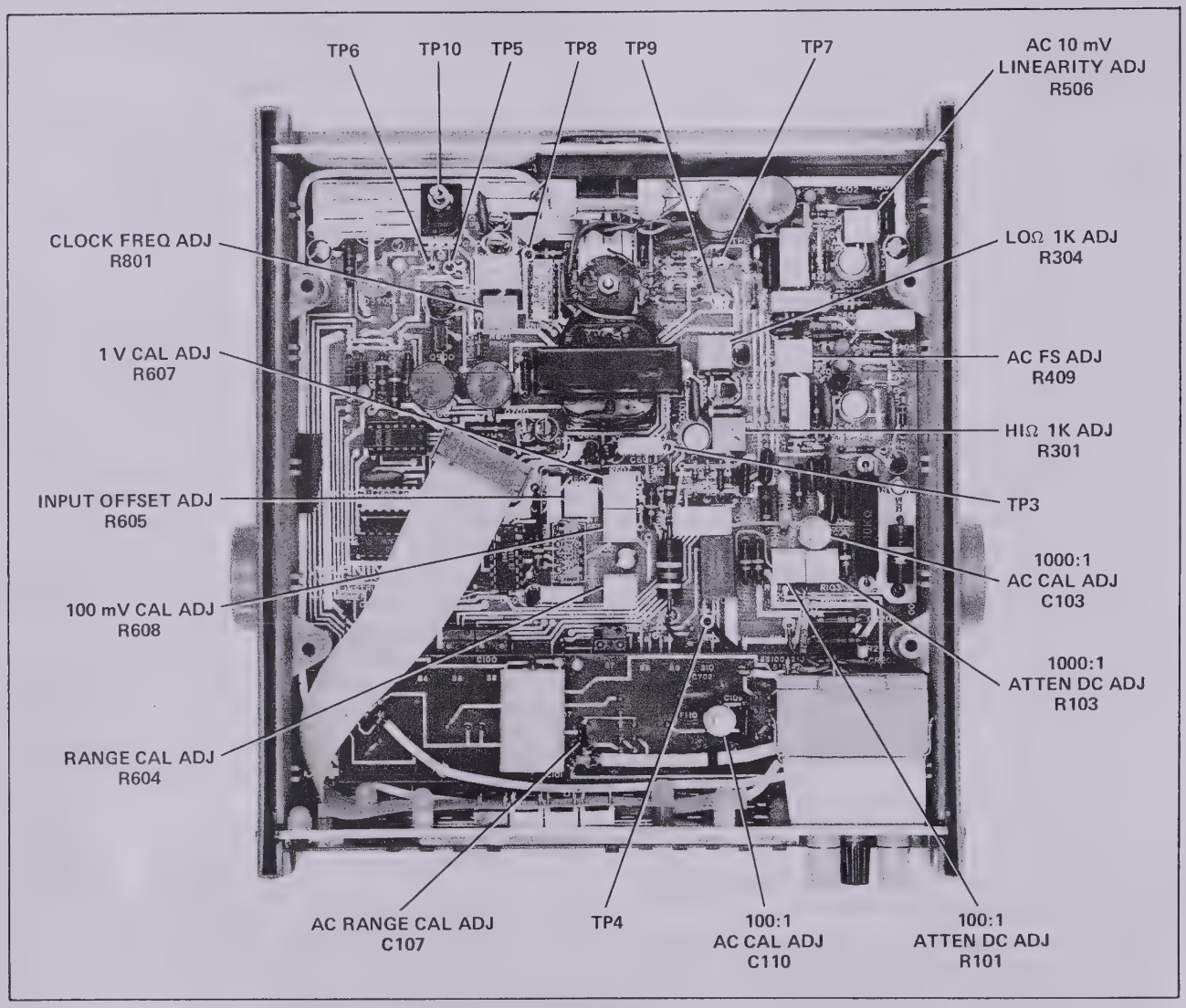


Figure 5–1. Location of Internal Adjustment and Test Points

5–38. Initial Power Supply Checks.

5–39. The 3028A has no power supply adjustments but line voltage regulation should be checked before calibration. Vary ac power line voltage with a variac from 102 to 130 volts (or over the limits given for the operating range selected when using Option 06). Monitor the three dc power supply voltages of the DMM and observe voltages listed in Table 5–7 with a dc voltmeter.

5–40. Calibration.

5–41. All calibration is performed with ac power turned ON and ac line voltage set to 117 volts (or in the middle of the range selected when using Option 06).

CAUTION

Always perform the calibration in the sequence indicated below.

5–42. Clock Frequency Adjust R801.

a. Connect digital frequency counter input to Test Point 8. Ground the counter input to the COMMON input connector of the DMM.

b. Adjust R801 for a counter reading of 24.56 kHz when using 60 Hz power or 25.6 kHz when using 50 Hz power. The setting should be within ± 150 Hz.

5–43. Input Offset Adjust R605 and DC Polarity Reversal Test.

a. Set DMM to DC, V, and 100 m.

b. Short input connector V–Ω to COMMON.

c. Adjust R605 (Input Offset Adj.) for a display reading of 00.0. Note that the display does not change ± 1 count more than ten times in ten seconds.

d. Remove input short and connect a dc voltage to V–Ω and COMMON. Set the input voltage for any display reading between +170.0 and +190.0 and note display reading.

e. If batteries Option 05 is installed disconnect ac power and observe that reading noted in Step d. does not change more than ± 1 digit. Charge batteries or troubleshoot if reading changes more than ± 1 digit. Restore ac operation for remainder of test.

f. Reverse input leads at the V–Ω and COMMON connectors. Observe that the negative of the display reading noted in Step d. does not change more than ± 2 digits for turnover error. If the change is greater compromise the adjustment of R605 by averaging the setting between steps c. and f. For optimum results it may be necessary to add R603 which is a resistor in the range of 360 K to 910 K. R603 is typically 560 K.

5–44. Range Cal Adjust R604.

a. Set R607, the 1 volt adjust and R608 to 100 mV adjust potentiometers at the center of their range.

b. Connect the dc voltage calibrator to the V–Ω and COMMON input connectors of the DMM. Apply +190.00 mV.

c. Set DMM controls.

d. Adjust R604 (2 V Adj.) for a DMM display reading of +190.0 ± 10 digits.

5–45. 100 mV Cal Adjust R608.

a. Maintain the test set up of paragraph 5–44.

b. Adjust R608 (100 mV Cal Adj.) for a DMM display reading of exactly +190.0.

5–46. 1 V Cal Adjust R607.

a. Maintain the test set up of paragraphs 5–44 and 5–45.

b. Set DMM to DC, V, and 1.

c. Set dc voltage calibrator to +1.9000 volts.

d. Adjust R607 (1 V Cal Adj.) for a DMM display reading of exactly +1.900.

5–47. LOΩ 1 K Cal Adjust R304.

a. Set DMM to LOΩ and 1 K.

b. Connect resistance standard to V–Ω and COMMON connectors and set standard to 1.900 k Ω.

c. Adjust R304 (LOΩ/1 k Cal Adj.) for a DMM display reading of 1.900. If R304 does not cover the range, select R303 by changing to 7.50 k, 8.25 k or 9.06 kΩ or replace Q302.

5–48. 1000 to 1 Attenuator DC Adjust R103.*

a. Set DMM to LOΩ and 10 kΩ.

b. Connect 19.00 kΩ resistance standard to the DMM input.

c. Adjust R103 for a DMM display reading of 19.00.

d. Disconnect Resistance Standard.

5–49. 100 to 1 Attenuator DC Adjust R101.

a. Set DMM to DC, V, and 1000.

b. Connect dc voltage standard to the V–Ω and COMMON input connectors. Apply +1000.0 V.

c. Adjust R101 (100 to 1 Att. DC Adj.) for a DMM display reading of +1000.

5–50. Recheck 100 Volt Range DC Calibration.

a. Set DMM to DC, V, and 100.

b. Connect dc voltage standard to the DMM and apply +100.00 V.

c. DMM display should read +100.0. If required touch up R103 to obtain +100.0. If the display error was more than ± 3 digits repeat paragraph 5–48.

*Not used when R102 is 90 kΩ, 1 W, 0.05%.

5–51. HIΩ 1 K Cal Adjust R301.

a. Set DMM to HIΩ and 1 K.

b. Connect 1.9000 kΩ resistance standard to the V–Ω and COMMON connectors.

c. Adjust R301 (HIΩ 1 k Cal Adj.) for a DMM display reading of 1.900.

d. Switch DMM to LOΩ and check that DMM display reads 1.900 ± 3 digits or repeat paragraph 5–47.

e. Change resistance standard to 190.00 kΩ and set DMM to HIΩ and 100 k. Check that DMM display reads 190.0 ± 3 counts or repeat steps a through c.

5–52. AC 10 mV Linearity Adjust R506.

a. Set DMM to AC, V, and 100 m.

b. Apply 10 mV at 400 Hz.

c. Adjust R506 (AC 10 mV LIN Adj.) for a DMM display of 01.0.

5–53. AC Full Scale Adjust R409.

a. Set DMM to AC, V, and 100 m.

b. Short V–Ω to COMMON input connectors.

c. Check that DMM display reads 00.0 to 00.4.

d. Remove input short and connect the ac voltage calibrator to V–Ω and COMMON.

e. Apply 190.00 mV at 400 Hz.

f. Adjust R409 (AC FS Adj.) for a DMM display reading of 190.0.

g. Repeat steps 5–52 and 5–53.

5–54. AC 1000 to 1 Cal Adjust C103 and Range Cal Adjust C107.*

a. Set DMM to AC, V, and 1000.

b. Connect the ac voltage calibrator to the V–Ω and COMMON input connectors.

c. Apply 1000.00 volts at 400 Hz.

d. Observe that the DMM display reads 990 to 1010. If not recheck paragraphs 5–52 (R409), 5–49 (R101) and 5–48 (R103).

e. Increase ac voltage calibrator frequency to 50 kHz.

f. Adjust C103 (AC 1000 to 1 CAL ADJ.) until the display reads 997 to 1002.

g. Set ac voltage calibrator to 5 kHz and note that the display reads 997 to 1003. If display reads above 1003 set calibrator to OFF and carefully trim 2 mm from the end of twin lead capacitor C107 (AC RANGE CAL ADJ). Cut diagonally to provide a long leakage path. Check adjustment of C103 at 50 kHz after each trim.

*Simulate capacitive effects of top cover when performing this adjustment.

If display reads below 997 at 5 kHz, replace C107 with a new and longer twin lead and repeat the above trimming procedure until the 5 kHz and 50 kHz response points are 990 to 1010 and 994 to 1005 respectively.

CAUTION

Always turn ac voltage calibrator OFF to prevent shock hazard when trimming C107.

5–55. AC 100 to 1 Cal Adjust C110.*

a. Set DMM to AC, V, and 10.

b. Connect the ac voltage calibrator to the DMM input.

c. Apply 19.000 volts at 400 Hz.

d. Observe that the DMM display reads 19.00 ± 3 digits.

5–56. TROUBLESHOOTING AND FAULT FINDING.

5–57. The troubleshooting procedures should only be performed when the instrument cannot be calibrated with the calibration procedures listed in paragraphs 5–31 through 5–54. Should the instrument be inoperative or out of specification, follow the fault finding procedures listed below.

5–58. Carefully examine the instrument and check for any visual evidence of trouble. Check for broken wires, burned resistors, loose components, shorts, or open or defective solder joints on the printed circuit board. Check for separation of printed circuit board lands and pads. Check for open, defective, or intermittent switches. Check that connectors are clean and will mate properly. Check that instrument circuit ground is properly connected to the metal coating shield on the plastic case top, bottom and side supports. Check that the power line earth ground is connected only to the front and rear panels. Troubleshoot with COMMON connected to power line earth ground.

5–59. Understand and be familiar with the circuit theory of Section 4. Use the functional block diagram of Figure 4–1 and the schematic diagram to isolate the probable circuit areas which may cause the problem. Always check the power supply voltages. Check for oscillations in the circuitry by using an oscilloscope. Then refer to the fault finding and troubleshooting hints for that circuit. Table 5–8 gives some probable corrections for specific symptoms.

5–60. **NOTE:** All tests and calibration procedures listed herein consider the normal service conditions of 15°C to +35°C. Should a service condition temperature range of 20°C to 40°C be required then all the calibration settings listed above must be offset to reflect the increased temperature range. Calibrate the instrument with the ambient temperature at 22°C to 25°C and make adjustments by subtracting two least significant digits from the digital display to reflect the higher service condition range of 20°C to 40°C.

5–61. FUSE REPLACEMENT.

5–62. The ac power line fuse F50 is located on the inside of the rear panel. To replace the fuse, remove the covers as described in paragraph 5–33, remove the defective fuse, and snap in the replacement fuse.

5–63. PREVENTIVE MAINTENANCE.

5–64. **Cleaning.** The instrument should be cleaned as often as operating conditions require. Thoroughly clean both the inside and outside of the instrument. Remove dust from inaccessible areas with low pressure compressed air or vacuum cleaner. Use alcohol applied with a cleaning brush to remove accumulations of dirt or grease from connector contacts and component terminals. Clean the exterior of the instrument and the front panel with a mild detergent mixed with water, applying the solution with a soft, lint-free cloth.

5–65. **Repair and Replacement.** Repair and replacement of electrical and mechanical parts must be accomplished with care and caution. Printed circuit component boards can become warped, cracked, or burnt from excessive heat or mechanical stress. The following repair techniques are suggested to avoid inadvertent destruction or degradation of parts and assemblies.

a. Use a low-heat capacity soldering iron (Weller Model No. W-TCP 35 watt) soldering iron with a 700°F tip 1.5 mm (1/16") to 2.5 mm (3/32") wide.

b. Be sure that the soldering iron tip and the cabinet and COMMON connectors are securely tied to "earth" ground. This avoids possible overvoltage damage to semiconductors and capacitors.

c. To desolder components, use a commercial "solder sipper," (SOLDA PULLT manufactured by Edsyn Products or equivalent) or use solder-removing SODER-WICK, size 3, manufactured by SOLDER REMOVAL CO., Covina, California.

d. To remove a component, clip a heat sink such as long nose pliers, tweezers, or alligator clips onto the component lead and as close to the body of the component as possible. This assures minimum heating of the component while soldering.

Place the soldering iron directly on the component lead on the printed circuit conductor side of the board. Use a desoldering aid to remove all solder and free the component lead.

Straighten the bent over component lead with long nose pliers.

Pull the component out of the hole.

If a component is obviously faulty or damaged, simply clip the leads close to the body of the component and remove the remaining leads thru the conductor side of the circuit board.

CAUTION

Always use a short soldering cycle since excessive or prolonged heat may destroy the laminate bond and lift the copper conductors from the circuit board or cause immediate degradation or latent damage to the components.

e. Always clean the component lead holes by heating the solder on the circuit board conductor pad, then quickly remove the soldering iron and insert a pointed non-metallic object such as a toothpick to clean the hole. Never let solder cover the hole, since the incoming new component lead may then push the pad from the circuit board.

f. To install a new component, straighten and shape the leads. Insert the component into the proper holes. Bend the leads at the conductor side of the circuit board so they fall over the pad and extend over the foil of the incoming conductor path. Cut the bent lead approximately 2.5 mm (3/32") from the hole.

Clip a heat sink to the component lead at the body of the component. Heat the lead and pad with a soldering iron and use fresh solder (60-40) as required to cover the lead and form a meniscus over the hole to assure a good electrical connection.

g. Clean excess flux from the connection and surrounding area. Use TF Freon spray cleaner (such as Miller Stevenson Chemical Co., Type MS-180, Ballantine P/N 80-10004-0A) and use light air pressure (5 to 20 PSIG) and a clean soft brush to clean board and components. Use a humidity seal spray (such as Humiseal, Columbia Technical Corp., 1015, Ballantine P/N 80-10005-0A) to seal board and protect against humidity.

Note

Do not touch cleaned board or excessively handle components to avoid unwanted leakage which may affect performance when exposed to high humidity.

h. Always replace a component with its exact duplicate as specified in the parts list.

5–66. REPLACING PUSHBUTTON SWITCHES.

a. Pushbutton switches may be disassembled for replacement of worn switch wipers and return springs. This saves unsoldering the multicontact switch. New parts must be taken from replacement switch assemblies which may be ordered as spare parts. To obtain access to pushbutton switches remove front panel and pushbuttons. Hold the return spring. Use a long nose plier to pull up and away on the "U" shaped retainer. Remove the spring. On S1 and S2 free the detent spring and pin. Carefully slide the switch bar out the rear of the switch. Access is then obtained to the individual switch contact sliding springs. Clean the switch and lubricate contacts.* Place the new contact springs into the switch bar and carefully reassemble the switch bar thru the rear of the switch assembly. To simplify assembly

reinsert two switch contact slider springs at a time. When all contact slider springs are in place and the push bar is fully extended out the front of the housing, replace the detent, the return spring and the "U" retainer. Operate the rebuilt switch several times to be sure all parts are in place. Then reassemble and test the instrument.

b. It is recommended that all contact slider springs be replaced in all 12 switches. If the entire switch assemblies are to be replaced, unsolder the small upper printed wiring board. Then use a solder pot or solder wave (rather than soldering iron and solder sucker) to remove the switch assemblies.

c. Do not clean switch with Freon or other solvents. Periodically lubricate all switch contacts with a light application of spray lubricant.*

*Use switch contact lubricant and cleaner such as Electrolube Contact Treatment Oil 2AX, Ballantine P/N 80100090A, or equivalent.

TABLE 5–8. TROUBLESHOOTING AIDS

1. Digital display does not illuminate when power switch is "ON."	1. AC power cord not properly inserted or connected. Check power line fuse F50. Check condition of Q800 and Q801, the DC/DC converter drivers, and U900 +5 volt regulator as well as rectifiers, CR900, and power switch S1. Check power supply voltages: +12 volts measures between +11.5 to +14.7 V +5 volts regulated measures between +4.2 to +5.3 V −12 volts measures between −11.5 to −14.7 V +5 volts unregulated measures between 7 and 13.5 V Replace appropriate components if measurements indicate out of tolerance voltages. Check for other faulty components that cause heating and excessive current drain. Check display drivers U701 and U702. Check Display Test. Replace components if fault is found.
2. Display does not read 0.000 to ±.0001 with 1 V range, V and DC function and V–Ω connector shorted to common.	2. Check clipping diodes CR601 and CR602, if installed, or U300. Short pin 15 of U600 to the common input connector. If display does not show −00.2 to +00.2, check or replace U600 and U700, and display driver circuitry. Check Q601 and measure 6.8 to 9.5 volts across this voltage reference zener. Adjust R605 (Input Offset Adj.) per paragraph 5–43.
3. 10% of Full Range Check. Connect +100 mV DC to the V–Ω and COMMON connectors. Select V and DC FUNCTION and 1 V RANGE.	3. If readout does not read 0.1000, connect input signal to the junction of R600 and S12A. If the display now reads 0.1000, check S12A, S5E, S6B, S3B, S2E, and S12B for poor connections. If the display does not read +0.100, transfer the input signal to the junction of CR601 and CR602. Check CR601 and CR602 if the display reads 0.100. If the display does not read 0.100, transfer the input signal to pin 15 of U600. If the display does not read 0.100, check U600, U700 and their related components.

TABLE 5–8. TROUBLESHOOTING AIDS (Continued)

4. Display Test Check. Push V and mA pushbuttons.	4. If the display does not read 888, check or replace U702, the decoder driver. Check the +5 volt regulated supply to see that it measures +4.2 to +5.3 volts. If one digit is not functioning, check U701. If some segments of the display are not lit, sequentially tie pins 9 thru 15 of U702 to the +5 volt supply and observe that one row of segments of the display are lit at any one time. This checks faulty U702 decoder driver. Also check RN700 and the LED readout DS750 thru DS752 and its flex print cable assembly.
5. Full Range Check. Connect +1.900 volts DC to the V–Ω and COMMON connectors. Select V and DC FUNCTION and 1 V RANGE.	5. Observe +1.900 ± 2 digits. If display is not in tolerance, recalibrate R608 and R607 the 100M volt and 1 volt RANGE calibrators. Also check switches S5A, S7E, S6F, S4D and S9B. Check reference diode Q601. Check clock frequency adjustment R801. Use a frequency counter to check cycle frequency, 24.56 kHz for 60 Hz operation, and 25.6 kHz for 50 Hz power line operation. If either "1" digit of display or "+" symbol does not light up, check DS753, Q700, Q701, U701, S2B, S3D, and S4E.
6. Check negative sign. Repeat step 5 but apply –1.8 V DC.	6. Negative sign must illuminate on DS753. If no, check U700, U701, Q700, and Q701. If display reads more than 3 digits difference between plus input polarity (step 5) and minus input polarity (step 6), check for leaky diodes CR601 and CR602. Check U3 for excessive input current and clean P. C. board since leakage may exist at the input leads between V–Ω connector and pin 15 of U600. Check adjustment of R605 (Input Offset Adj.) since it also controls polarity turnover error. See paragraph 5–43.
7. Decimal Point Test. Select DCmA FUNCTION AND 1000 mA RANGE.	7. Observe that no decimal point is lit and the display reads –002 to +002 Select 100 mA RANGE and observe that the display reads –00.2 to +00.2. Select 10 mA RANGE and observe that the display reads –0.02 to +0.02. Select 1 mA RANGE and observe that the display reads –.002 to +.002. Select 100 μA RANGE and observe that the display reads –00.2 to +00.2. If any of these decimal points do not light check the respective LED (DS750 thru DS752). Check R705, S7C, S9E, S10E, and S12D.

TABLE 5–8. TROUBLESHOOTING AIDS (Continued)

8. Accuracy Tests. See details in Performance Assurance Checks (paragraph 5–7).	8. DC volt calibration not OK, check input voltage divider R101, R102, R103, R104, R600, R601, and their associated switches. KΩ tests not OK then check U300, constant correct source Q300, Q301 and Q302, and their associated components. If 100 Ω RANGE faulty, also check R303 and R304 as well as S5B and S6E. Also check S3E, S4B, S7B, S10D, and S5C. DC mA tests not OK, check current shunt resistor DIP RN200 as well as condition of CR200 thru CR204. Check associated switches. AC voltage tests not OK, check AC converter U400, Q400, Q401, U500, and associated switches and components. AC mA tests not OK, recheck DC mA tests and AC voltage tests. Then check S4A, S2D, S2A, and S3A.
9. Intermittent Switches.	9. When the multimeter has been stored for a period of time or has been exposed to caustic fumes, acid fumes, oil fumes, hydrogen sulfide, or other contaminants, the pushbutton switches may become noisy or intermittent even though specially treated high-quality silver-plated contacts are used throughout. Push each button ten or more times to permit self-wiping action of switches to clean the contacts and eliminate the problem. If at the end of life or after extensive exposure the switches continue to be noisy, they should be replaced with new components. Periodically lubricate switches with silicone spray contact lubricant.
10. Battery Operation Not Functional.	10. Check that batteries are charged and or charge batteries for 8 to 16 hours. Replace batteries when they do not power DMM for at least 3 hours. Open top cover and check that batteries are installed and seated properly. Observe that ballast lamp DS900 is installed and lights brightly to indicate batteries are charging when POWER switch (S1) is OFF and ac line power is applied.

PERFORMANCE TEST RECORD

BALLANTINE MODEL 3028A, OPTION 39A SERIAL NUMBER _____

1.	120-Volt Check	(0.00 ±3LSD)	_____ (✓)
2.	Display Test	(888)	_____ (✓)
3.	102-Volt Lo Line Check	(0.00 ±3LSD)	_____ (✓)
4.	130-Volt HI Line Check	(0.00 ±3LSD)	_____ (✓)
5.	Battery Test	(>5 volts)	_____ (✓)

6. DC Voltage Calibration Check

Calibrator Voltage	DMM			
	Range	Function	Readout Display Limits	Reading
0.0000	100 m	VDC	−00.1 to +00.1	
+0.0100	100 m	VDC	+09.8 to +10.2	
+0.1000	100 m	VDC	+99.8 to +100.2	
−0.1000	100 m	VDC	−99.8 to −100.2	
+0.1800	100 m	VDC	+179.7 to +180.3	
+1.0000	1	VDC	+.998 to +1.002	
+10.000	10	VDC	+9.98 to +10.02	
+100.00	100	VDC	+99.8 to +100.2	
+1000.0	1000	VDC	+998 to 1002	

7. DC Current Calibration Check

DC Current Calibrator	DMM		
	Range	Readout Limits	Reading
00.0 μA	100 μ	−00.2 to +00.2	
+100 μA	100 μ	+99.5 to +100.5	
+1.000 mA	1 m	+.995 to +1.005	
+10.00	10 m	+9.95 to +10.05	
+100.0	100 m	+99.5 to +100.5	
+1000	1000 m	+995 to +1006	

Form 5–1, Performance Test Record

8. AC Voltage Calibration Check

AC Voltage Calibrator		DMM		
Voltage	Frequency	Range	Display Limits	Reading
0000 mV	500 Hz	100 m	00.0 to 00.5	
10.00 mV	500 Hz	100 m	09.7 to 10.3	
100.00 mV	500 Hz	100 m	98.8 to 101.2	
100.0 mV	5 kHz	100 m	98.8 to 101.2	
100.0 mV	50 kHz	100 m	97.8 to 102.2	
180 mV	500 Hz	100 m	178.0 to 182.0	
180 mV	50 kHz	100 m	175.8 to 184.2	
1.000 V	500 Hz	1	.988 to 1.012	
1.000 V	5 kHz	1	.988 to 1.012	
1.000 V	50 kHz	1	.978 to 1.022	
10.00 V	500 Hz	10	9.88 to 10.12	
10.00 V	50 kHz	10	9.78 to 10.22	
100.0 V	500 Hz	100	98.8 to 101.2	
100.0 V	50 kHz	100	97.8 to 102.2	
1000.0 V	500 Hz	1000	988 to 1012	
1000.0 V	50 kHz	1000	978 to 1022	

9. Ohms Calibration Check

Resistance Standard	Function	DMM		
		Range	Display Limits	Reading
0000	LOΩ	100	00.0 to 00.6	
100.00	LOΩ	100	99.4 to 100.6	
1.0000 k	LOΩ	1 K	994 to 1006	
1.0000 k	HIΩ	1 K	994 to 1006	
10.000 k	LOΩ	10 K	9.94 to 10.06	
10.000 k	HIΩ	10 K	9.94 to 10.06	
100.00 k	LOΩ	100 K	99.4 to 100.6	
100.00 k	HIΩ	100 K	99.4 to 100.6	
1.0000 M	LOΩ	1000 K	980 to 1020	
1.000 M	HIΩ	1000 K	994 to 1006	
1.000 M	HIΩ	10 M	9.79 to 10.2	

Signature *Date*

Ballantine Laboratories, Inc.
P.O. Box 97, Boonton, New Jersey 07005, U.S.A.
Telephone: 201-335-0900 TWX: 710-987-8380

SECTION 6

REPLACEABLE PARTS LIST AND CIRCUIT SCHEMATIC DIAGRAMS

The replacement parts listed are available from the vendors or from Ballantine Labs. Your local Ballantine Field Engineering Representative may also carry a stock of parts and can assist you. If pricing quotations are required for parts and or repairs your local representative will give the most rapid service or you may contact the Ballantine Factory directly:

Instrument Service Department
Ballantine Laboratories, Inc.
P.O. Box 97
90 Fanny Road
Boonton, N.J. U.S.A. 07005

When ordering replacement parts always give the following information:

a) Instrument Model number
b) Serial number
c) Ballantine Part number
d) Schematic Symbol number
e) Identification of the part

Ballantine will do its best to improve the instrument and make changes in style of components and replacement parts. Replacement parts may differ in appearance from those found in your instrument but are always equal or superior in performance. Where necessary, minor mechanical modifications may be required in the replacement of components.

Parts are generally available locally for most replacements. The parts list calls out the recommended vendors where applicable. Always use the exact part called out in the parts list or an equivalent approved by Ballantine to ensure that all performance specifications will be met.

The Manufacturer Code is taken from Federal Supply Code Cataloging Handbooks H4-1, H4-2, and H4-3. Ballantine Code is 50423.

The following parts coding are used:

CVC Capacitor, Variable, Ceramic
CEP Capacitor, Fixed, Plastic
CCD Capacitor, Ceramic, Disc
CYF Capacitor, Mylar, Foil

CMD Capacitor, Mica, Dipped
CMM Capacitor, Mica, Molded
CEA Capacitor, Electrolytic, Aluminum
CET Capacitor, Electrolytic, Tantalum

DGP Diode, General Purpose
DZG Diode, Zener, General Purpose
DRP Diode, Bridge, Power
FLT Filter
ICP Integrated Circuit

TRQ Transistor

RFF Resistor, Fixed, Film
RFC Resistor, Fixed, Composition
RFW Resistor, Fixed, Wirewound

SWC Switch

LMP Lamp

TRX Transformer

Resistors may generally be replaced by Corning Electronics (CCW) type N-55, N-60, and C-32. Allen Bradley composition resistors type EB are also used.

SCHEMATIC REF	BALLANTINE PART NO.	DESCRIPTION	MFR CODE	MFR PART NUMBER
C 100	07103360A	CBM 47.0NF 1.6KV +-10%	80031	MEPCO C281/1600/A47K
C 101	07103551A	CTE 4.5PF 1.2KVJ	50423	BLI 3028A SPEC-WIRE
C 102	07103490A	CMD 560.0PF 500.0 V TCE 1%	84171	ARCO DM15ED560F03 ARCO
C 103	07103600A	CVC 10-60PF 350.0 V N750	50423	
C 104	07103500A	CMD 470.0PF 500.0 V TCE 2%	84171	ARCO DM15ED470G03 ARCO
C 105*	07103540A	CMD 1.0 NF 500 V +-1%	84171	ARCO DM19ED1000FNJ N-U
C 105	07104180A	CMD 750 PF 300 V VJ +-5%	53201	SANGAMO CM05ED751J03
C 106	07101030A	CMD 250.0PF 500 V +-5%	84171	ELMENCO DM1525J
C 107	07103471A	CVE 1.2PF 1.2KVJ	50423	BLI 3028A SPEC.WIRE
C 108	07202510A	CMD 47.0PF 1.5KV 5%	84171	ARCO DM15-E-H-470-J-N-1
C 109	07022860A	CMD 39 PF 500 V J 5%	84171	ARCO TYPE DM-15-390-J
C 110	07103600A	CVC 10-60PF 350.0 V N750	50423	
C 300	07022600A	CMD 100 PF 500 V J 5%	84171	ARCO TYPE DM-15-101-J
C 301	07101980A	CCD 100.0NF 25.0 V NPO	56289	SPRAG C069A250M1042 OR EQ
C 401	07101980A	CCD 100.0NF 25.0 V NPO	56289	SPRAG C069A250M1042 OR EQ
C 403	07103410A	CBM 470.0NF 100.0 V +-10%	80031	MEPCO C280MCH/A470K
C 404	07101980A	CCD 100.0NF 25.0 V NPO	56289	SPRAG C069A250M1042 OR EQ
C 406	07102580A	CET 68.0UF 15.0 VK DIP TAN	56289	SPRAG 196D686X9015-LA3
C 407	07101790A	CET 22.0UF 15.0 VM	56289	SPRAGUE 196D226X0015KE3
C 408	07101790A	CET 22.0UF 15.0 VM	56289	SPRAGUE 196D226X0015KE3
C 40°	07100040A	CMD 300.0PF 500.0V DM15	84171	ARCO DM-15-301J
C 410	07103410A	CBM 470.0NF 100.0 V +-10%	80031	MEPCO C280MCH/A470K
C 500	07103410A	CBM 470.0NF 100.0 V +-10%	80031	MEPCO C280MCH/A470K
C 501	07103580A	CBM 1.0UF 100.0 VK MET POL	80031	MEPCO C280MCH/A1M
C 502	07101980A	CCD 100.0NF 25.0 V NPO	56289	SPRAG C069A250M1042 OR EQ
C 503	07101980A	CCD 100.0NF 25.0 V NPO	56289	SPRAG C069A250M1042 OR EQ
C 504	07101170A	CMD 12.0PF 500.0 VJ	84171	ELMENCO DM15C120JN
C 600	07103370A	CBM 68.0NF 630.0 V +-10%	80031	MEPCO C280MCG/A68K
C 601	07103380A	CBM 33.0NF 400.0 V +-10%	80031	MEPCO C280MCF/A33K
C 602	07103390A	CBM 100.0NF 100.0 V +-10%	80031	MEPCO C280MCH/A100K
C 603	07202510A	CMD 47.0PF 1.5KV 5%	84171	ARCO DM15-E-H-470-J-N-1
C 605	07103400A	CBM 22.0NF 400.0 V +-10%	80031	MEPCO C280MCF/A22K
C 700	07101790A	CET 22.0UF 15.0 VM	56289	SPRAGUE 196D226X0015KE3
C 701	07101790A	CET 22.0UF 15.0 VM	56289	SPRAGUE 196D226X0015KE3
C 702	07101980A	CCD 100.0NF 25.0 V NPO	56289	SPRAG C069A250M1042 OR EQ
C 703	07101980A	CCD 100.0NF 25.0 V NPO	56289	SPRAG C069A250M1042 OR EQ
C 800	07103380A	CBM 33.0NF 400.0 V +-10%	80031	MEPCO C280MCF/A33K
C 801	07103380A	CBM 33.0NF 400.0 V +-10%	80031	MEPCO C280MCF/A33K
C 802	07103420A	CEA 100.0UF 6.0 V +-10%	50423	
C 803	07103060A	CEA1000.0UF 16.0 V STANDUP	50423	
C 804	07103060A	CEA1000.0UF 16.0 V STANDUP	50423	
C 805	07101980A	CCD 100.0NF 25.0 V NPO	56289	SPRAG C069A250M1042 OR EQ
C 806	07101980A	CCD 100.0NF 25.0 V NPO	56289	SPRAG C069A250M1042 OR EQ
C 807	07101980A	CCD 100.0NF 25.0 V NPO	56289	SPRAG C069A250M1042 OR EQ
C 808	07101790A	CET 22.0UF 15.0 VM	56289	SPRAGUE 196D226X0015KE3
C 900	07103060A	CEA1000.0UF 16.0 V STANDUP	50423	
C °01	07103060A	CEA1000.0UF 16.0 V STANDUP	50423	
CB 10	19100351A	CBK 2A BREAKER FAST LNG SHFT	50423	BLI
CR 200	05100630A	DRP IN5400 50 3A	04713	MOT SI
CR 201	05100630A	DRP IN5400 50 3A	04713	MOT SI
CR 202	05100630A	DRP IN5400 50 3A	04713	MOT SI
CR 203	05100630A	DRP IN5400 50 3A	04713	MOT SI
CR 300	05100350A	DZG IN758A 10 20M .4	04713	MOT SI
CR 301	05100350A	DZG IN758A 10 20M .4	04713	MOT SI
CR 302	05079200A	DGP IN4148 75 10M	07263	FCH SI D035
CR 400	05079200A	DGP IN4148 75 10M	07263	FCH SI D035
CR 401	05079200A	DGP IN4148 75 10M	07263	FCH SI D035
CR 402	05079200A	DGP IN4148 75 10M	07263	FCH SI D035
CR 403	05079200A	DGP IN4148 75 10M	07263	FCH SI D035
CR 500	05079200A	DGP IN4148 75 10M	07263	FCH SI D035
CR 601	05094680A	DGP FD300 150 375M .4	07263	FCH SI D07
CR 602	05094680A	DGP FD300 150 375M .4	07263	FCH SI D07

*Used only in units with Serial No. Prefix 021-.

SCHEMATIC REF	BALLANTINE PART NO.	DESCRIPTION	MFR CODE	MFR PART NUMBER
CR 500	05079200A	DGP IN4148 75 10M	07263	FCH SI D035
CR 601	05094680A	DGP FD300 150 375M .4	07263	FCH SI D07
CR 602	05094680A	DGP FD300 150 375M .4	07263	FCH SI D07
CR 800	05079200A	DGP IN4148 75 10M	07263	FCH SI D035
CR 801	05079200A	DGP IN4148 75 10M	07263	FCH SI D035
CR 802	05079200A	DGP IN4148 75 10M	07263	FCH SI D035
CR 803	05079200A	DGP IN4148 75 10M	07263	FCH SI D035
CR 804	05100320A	DZG IN961B 10 12M .4	07263	FCH SI D07
CR 900	05100060A	DGP W04M 400 1.5A	04713	GIC
CR 901	05079200A	DGP IN4148 75 10M	07263	FCH SI D035
DS 750	21100160A	IND 0.4 IN COM CAT ORANGE LD	50522	MONSANTO 4640
DS 751	21100160A	IND 0.4 IN COM CAT ORANGE LD	50522	MONSANTO 4640
DS 752	21100160A	IND 0.4 IN COM CAT ORANGE LD	50522	MONSANTO 4640
DS 753	21100120A	IND 0.4 IN ORANGE +1 LED	26483	MONSANTO 4630
DS 900	16100230A	LMP CM-12 6.3V 150MA BI-PIN	71744	CHICAGO MINIATURE CM-12
F 50	19100360A	FUS .125A NORMAL-BLO	75915	LITTELFUSE TYP3AG NORMBLO
J 1	31301260A	CON FLEXPRINT 20 PINS PC MT	26394	ANSLEY 609 2003
J 1A	31301270A	ADA ADAPTER FOR 31301260A	26394	ANSLEY 609-W208
J 10	31101320A	BPS 10MM GREY	50423	
J 20	31101320A	BPS 10MM GREY	50423	
J 30	31101330A	BPS 10MM BLACK	50423	
J 50	31100000A	REC AC POWER	82389	SWITCHCRAFT
L 10	46100020A	FRB FER BD 4AMAT.047ID	02114	FERROX CUBE 56590 65/HA
L 20	46100020A	FRB FER BD 4AMAT.047ID	02114	FERROX CUBE 56590 65/HA
L 30	46100020A	FRB FER BD 4AMAT.047ID	02114	FERROX CUBE 56590 65/HA
Q 300	10100430A	TRQ 2N3904 NPN 1 40 PTO-92	04713	MOT 1 300M 40
Q 301	10100430A	TRQ 2N3904 NPN 1 40 PTO-92	04713	MOT 1 300M 40
Q 302	05100761B	DZG 2N4274 6.8V 1.5M+-10%	50423	BLI SELECT.FROM 05100763B
Q 400	10100580A	TRQ 40673 MOSFI 20 MTO-72	86684	RCA .350 400M 12K
Q 401	10094730A	TRQ 2N3906 PNP	04713	MOT 1 200M 60
Q 600	10100990A	TRQ E507	17856	SILICONIX
Q 601	05100761B	DZG 2N4274 6.8V 1.5M+-10%	50423	BLI SELECT.FROM 05100763B
Q 602	10100290A	TRQ 2N4400 NPN 1 40 PTO-92	04213	MOT 1 200M 20
Q 700	10100430A	TRQ 2N3904 NPN 1 40 PTO-92	04713	MOT 1 300M 40
Q 701	10094730A	TRQ 2N3906 PNP 1 40 PTO-92	04713	MOT 1 200M 60
Q 800	10100800A	TRQ 2N4403 PNP	04713	MOTOROLA
Q 801	10100800A	TRQ 2N4403 PNP	04713	MOTOROLA
Q 900	10100870A	TRQ 2N5193 PNP 1 40 P7703	04713	MOT 40 2M 10
R 100	12128670A	RFF 9.76M 2.0 W 1%	03888	PYROFILM PME 64T9 2.5KV
R 101	09100090A	RVC 250.0 K 0.5 WK +-10%	73138	HEL TYP 72PM
R 102	12128600A	RFF 88.7 K 1.0 W 1% 25PPM	16299	CGW NN650 OR EQUIV
R 103	09100020A	RVC 5.0 K 0.5 WK +-10%	73138	HEL TYP 72PM
R 104	12128610A	RFW 10.0 K 7.0 W 0.05%	50423	
R 105	12010100A	RFC 1.0 M 500 MW J+-5%	01121	A-B TYPE EB
R 106	12010260A	RFC 100.0 K 500.0MW J+- 5%	01121	A-B TYP EB
R 107	12010480A	RFC 4.7 K 500.0MW J+- 5%	01121	A-B TYP EB
R 108	12010030A	RFC 5.1 M 500 MW J+-5%	01121	A-B TYPE EB
R 200	12128730A	RFC 560.0 K 500.0MW	01121	A-B TYPE E-B
R 201	12128730A	RFC 560.0 K 500.0MW	01121	A-B TYPE E-B
R 300	12123890A	RFF 8.45K 500 MW F+-1%	16299	CGW RN60D 8451 F
R 301	09100050A	RVF 1.00K 0.5 WK CERMET	73138	HELIPOT 72PM
R 302	12123000A	RFF 1.0 K 500 MW F+-1%	16299	CGW RN60D 1001 F
R 303	12123890A	RFF 8.45K 500 MW F+-1%	16299	CGW RN60D 8451 F
R 304	09100050A	RVF 1.00K 0.5 WK CERMET	73138	HELIPOT 72PM
R 305	12010480A	RFC 4.7 K 500.0MW J+- 5%	01121	A-B TYP EB
R 400	12128630A	RFC 150.0 K 2.0 W 5%	01121	A-B HB
R 401	12010570A	RFC 1.0 K 500.0MWJ +- 5%	01121	A-B TYP EB
R 402	12010480A	RFC 4.7 K 500 MW J+-5%	01121	A-B TYPE EB
R 404	12010070A	RFC 2.0 M 500.0MW J+- 5%	01121	A-B TYP EB
R 405	12123280A	RFF 1.96K 500 MW F+-1%	16299	CGW RN60D 1961 F
R 406	12123280A	RFF 1.96K 500 MW F+-1%	16299	CGW RN60D 1961 F
R 408	12122920A	RFF 909.0 500 MW F+-1%	16299	CGW RN60D 9090 F

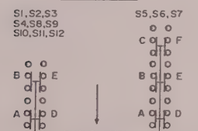
SCHEMATIC REF	BALLANTINE PART NO.	DESCRIPTION	MFR CODE	MFR PART NUMBER
R 411	12089580A	RCF 240.0 K 500.0MW J+- 5%	01121	A-B TYP EB
R 500	12089580A	RCF 240.0 K 500.0MW J+- 5%	01121	A-B TYP EB
R 501	12123280A	RFF 1.96K 500 MW F+-1%	16299	CGW RN60D 1961 F
R 502	12010720A	RFC 39.0 500.0MW J+- 5%	01121	A-B TYP EB
R 503	12010100A	RFC 1.0 M 500.0MW J+- 5%	01121	A-B TYP EB
R 504	12080210A	RFC 1.2 M 250.0MW J+- 5%	01121	A-B TYP CB
R 505	12010500A	RFC 3.9 K 500.0MW J+- 5%	01121	A-B TYP EB
R 506	09100030A	RVC 100.0 K 0.5 WK +-10%	73138	HEL TYP 72PM
R 507	12124520A	RFF 34.8 K 500 MW F+-1%	16299	CGW RN60D 3482 F
R 600	12128620A	RFC 560.0 K 2.0 W 5%	01121	A-B HB
R 601	12128730A	RFC 560.0 K 500.0MW	01121	A-B TYPE E-B
R 602	12010810A	RFC 27.0 K 500.MW J+- 5%	01121	A-B TYP EB
R 603	12128730A	RFC 560.0 K 500.0MW	01121	A-B TYPE E-B
R 604	09101460A	RVF 25.0 K 500.0MW TRIMPOT	73138	HELIPOT 72PM
R 605	09101460A	RVF 25.0 K 500.0MW TRIMPOT	73138	HELIPOT 72PM
R 606	12011380A	RFC 1.8 500.0MW K+-10%	01121	A-B TYP EB
R 607	09100020A	RVC 5.0 K 0.5 WK +-10%	73138	HEL TYP 72PM
R 608	09100010A	RVC 500.0 0.5 W K	73138	HEL TYP 72PM
R 610	12010810A	RFC 27.0 K 500.MW J+- 5%	01121	A-B TYP EB
R 700	12010480A	RFC 4.7 K 500.0MW J+- 5%	01121	A-B TYP EB
R 701	12010480A	RFC 4.7 K 500.0MW J+- 5%	01121	A-B TYP EB
R 702	12010480A	RFC 4.7 K 500.0MW J+- 5%	01121	A-B TYP EB
R 703	12010670A	RFC 150.0 500.0MW J+- 5%	01121	A-B TYP EB
R 704	12010670A	RFC 150.0 500.0MW J+- 5%	01121	A-B TYP EB
R 705	12011120A	RFC 470.0 500.0MW J+- 5%	01121	A-B TYP EB
R 706	12011300A	RFC 75.0 500.0MW J+- 5%	01121	A-B TYP EB
R 800	12010440A	RFC 10.0 K 500.0MW J+- 5%	01121	A-B TYP EB
R 801	09101070A	RVF 200.0 250.0MW K CER	73138	HEL TYPE 72PM-200
R 802	12089550A	RFC 360.0 500.0MW J+- 5%	01121	A-B TYP EB
R 900	12124640A	RFF 46.4 K 500 MW F+-1%	16299	CGW RN60D 4642 F
R 901	12123720A	RFF 5.62K 500 MW F+-1%	16299	CGW RN60D 5621 F
R 903*	12129350A	RFC 47 M 1.0 W K+-10%	01121	A-B TYPE GB
R 904*	12129340A	RFC 3.3 M 500 MW J+-5%	01121	A-B TYPE EB
RN 200	13100021A	RNW 3028A SHUNT RES,14DIP	50423	BLI
RN 600	13100001A	RNF 8 RES 14 DIP HI VALUE	50423	
RN 700	13100030A	RNF 8 RES,150 R,2%	80053	BECKMAN 898-3-R150
RN 800	13100011A	RNF 8 RES 14 DIP LO VALUE	50423	
S 1-6	25101241F†	SWC 3028A RMS 6PB RANGE	50423	
S 1-6	25101381L	SWC 3028A RMS 6PB RANGE	50423	
S 7-12	25101251F†	SWC 3028A RMS 6PB FUNCTION	50423	
S 7-12	25101391L	SWC 3028A RMS 6PB FUNCTION	50423	
T 800	20100291B	TRX 3028A DC/DC CONVERTER	50423	
T 900	20100311Q	TRX 3028A-39 POWER TRANS	50423	BLI REV 120 VOLT
T 900	20100301Q	TRX POWER (FOR OPTION 06)	50423	BLI
U 300	24101000A	ICP CA3130T OP AMP TO-5	86684	RCA
U 400	24101100A	ICP LM318 FAST OP AMP	27014	NATL SEMICON
U 500	24101000A	ICP CA3130T OP AMP TO-5	86684	RCA
U 600	24100931A	TCP DVM ANALOG 0.03%	17856	SILICONIX LD111 MODIFIED
U 700	24100941A	ICP DVM DIGITAL 3 1/2 DIGIT	17856	SILICONIX LD110 MODIFIED
U 701	24100840A	ICP SN7416N HEX INV 15V COLL	33809	TI OR EQUIV
U 702	24101090A	ICP MC 14511 7 SEGMENT DRIVE	04713	MOTOROLA OR EQUIV
U 900	24100010A	TCD UA7805	07263	FAIRCHILD

* Optional; used with high-voltage probes for safety purposes.
† Used only in units with Serial No. Prefix 021-.

NOTES:

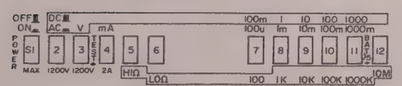
1. * DENOTES CALIBRATION ITEM, MOST FREQUENT VALUE SHOWN.
2. ⊘ DENOTES INTERNAL ADJUSTMENT.
3. S1 THRU S12 SHOWN IN OUT POSITION.
4. □ DENOTES PANEL MARKING.
5. OPTIONAL; USED WITH HIGH-VOLTAGE PROBES FOR SAFETY PURPOSES.
6. ▽ INPUT ATTEN AC COMPENSATION GND
   - ▽ HIGH QUALITY ANALOG INPUT GND
   - ▽ AC TO DC CONV GND
   - ▽ HIGH QUALITY AC TO DC GND
   - ▽ PWR SUPPLY GND
   - ▽ DIGITAL GND
7. NOT USED WHEN R102 IS 90 kΩ.
8. —●— INDICATES SOLDER CONNECTION WHICH MAY BE REMOVED TO ISOLATE CIRCUIT FOR TROUBLESHOOTING.
9. ALL CAPACITANCE VALUES ARE IN MICROFARADS AND ALL RESISTANCE VALUES ARE IN OHMS, UNLESS NOTED OTHERWISE.

TOP VIEW
SWITCH WIRING



S1 & S2 LATCHED INDIVIDUALLY
S3, S4, S5, S6 LATCH 1 OF 4
S7, S8, S9, S10, S11, S12 LATCH 1 OF 6

FRONT PANEL SWITCH MARKING



TOP VIEW J1

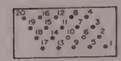
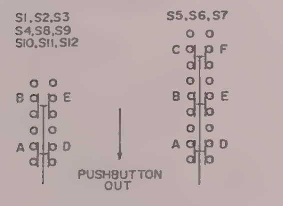


Figure 6–1. Model 3028A, Schematic Diagram (Serial No. Prefix 021-)

NOTES:

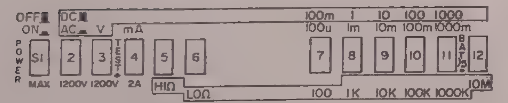
1. * DENOTES CALIBRATION ITEM. MOST FREQUENT VALUE SHOWN.
2. ⊘ DENOTES INTERNAL ADJUSTMENT.
3. S1 THRU S12 SHOWN IN OUT POSITION.
4. ▭ DENOTES PANEL MARKING.
5. OPTIONAL; USED WITH HIGH-VOLTAGE PROBES FOR SAFETY PURPOSES.
6. ▽1 INPUT ATTEN AC COMPENSATION GND
   ▽2 HIGH QUALITY ANALOG INPUT GND
   ▽4 AC TO DC CONV GND
   ▽6 HIGH QUALITY AC TO DC GND
   ▽8 PWR SUPPLY GND
   ▽9 DIGITAL GND
7. NOT USED WHEN R102 IS 90 kΩ.
8. —●— INDICATES SOLDER CONNECTION WHICH MAY BE REMOVED TO ISOLATE CIRCUIT FOR TROUBLESHOOTING.
9. ALL CAPACITANCE VALUES ARE IN MICROFARADS AND ALL RESISTANCE VALUES ARE IN OHMS, UNLESS NOTED OTHERWISE.

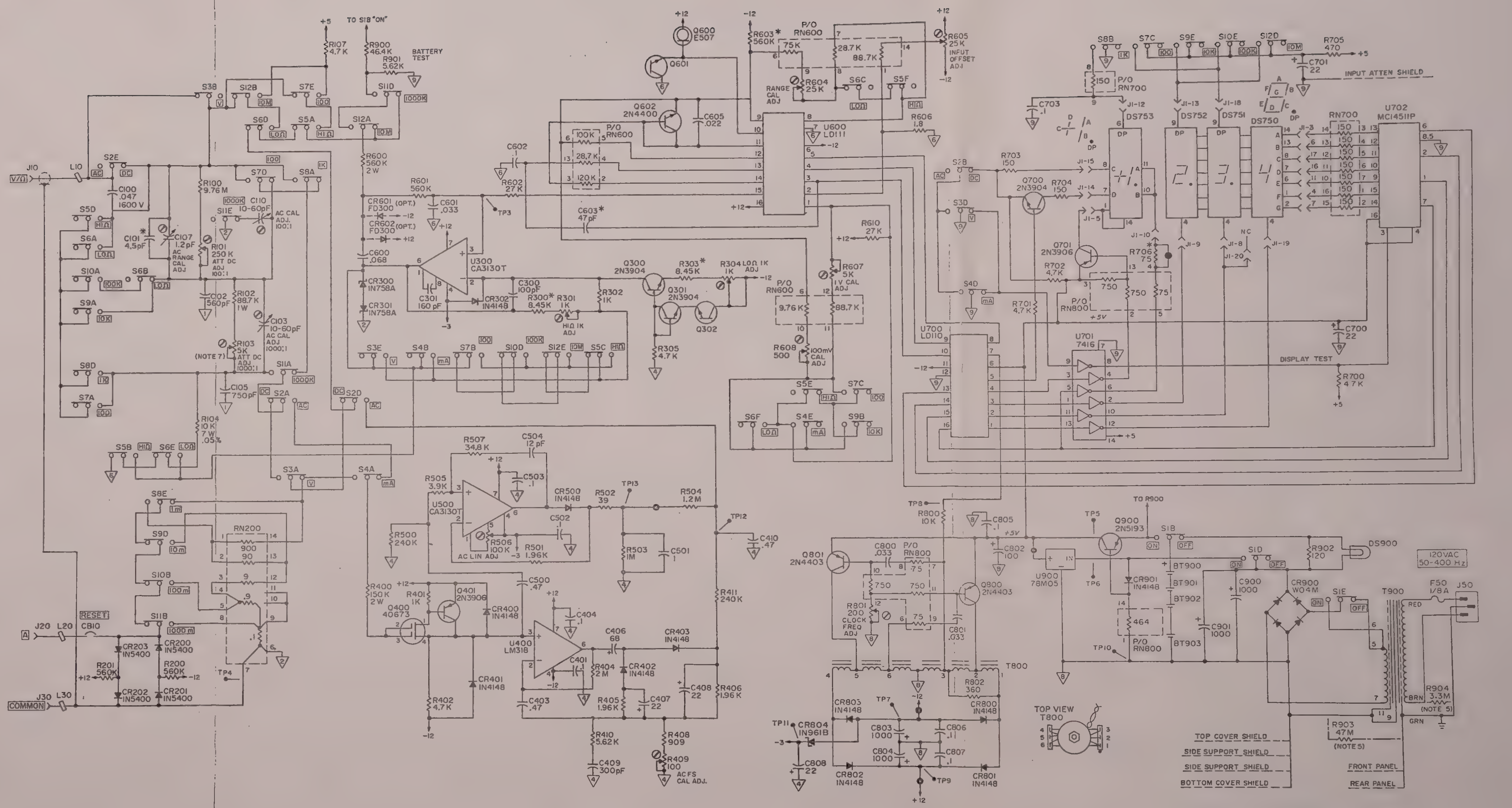
TOP VIEW
SWITCH WIRING



S1 & S2 LATCHED INDIVIDUALLY
S3, S4, S5, S6 LATCH 1 OF 4
S7, S8, S9, S10, S11, S12 LATCH 1 OF 6

FRONT PANEL SWITCH MARKING





TOP VIEW J1

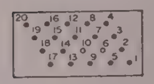


Figure 6-1. Model 3028A Schematic Diagram
(Serial No. Prefix 022-)

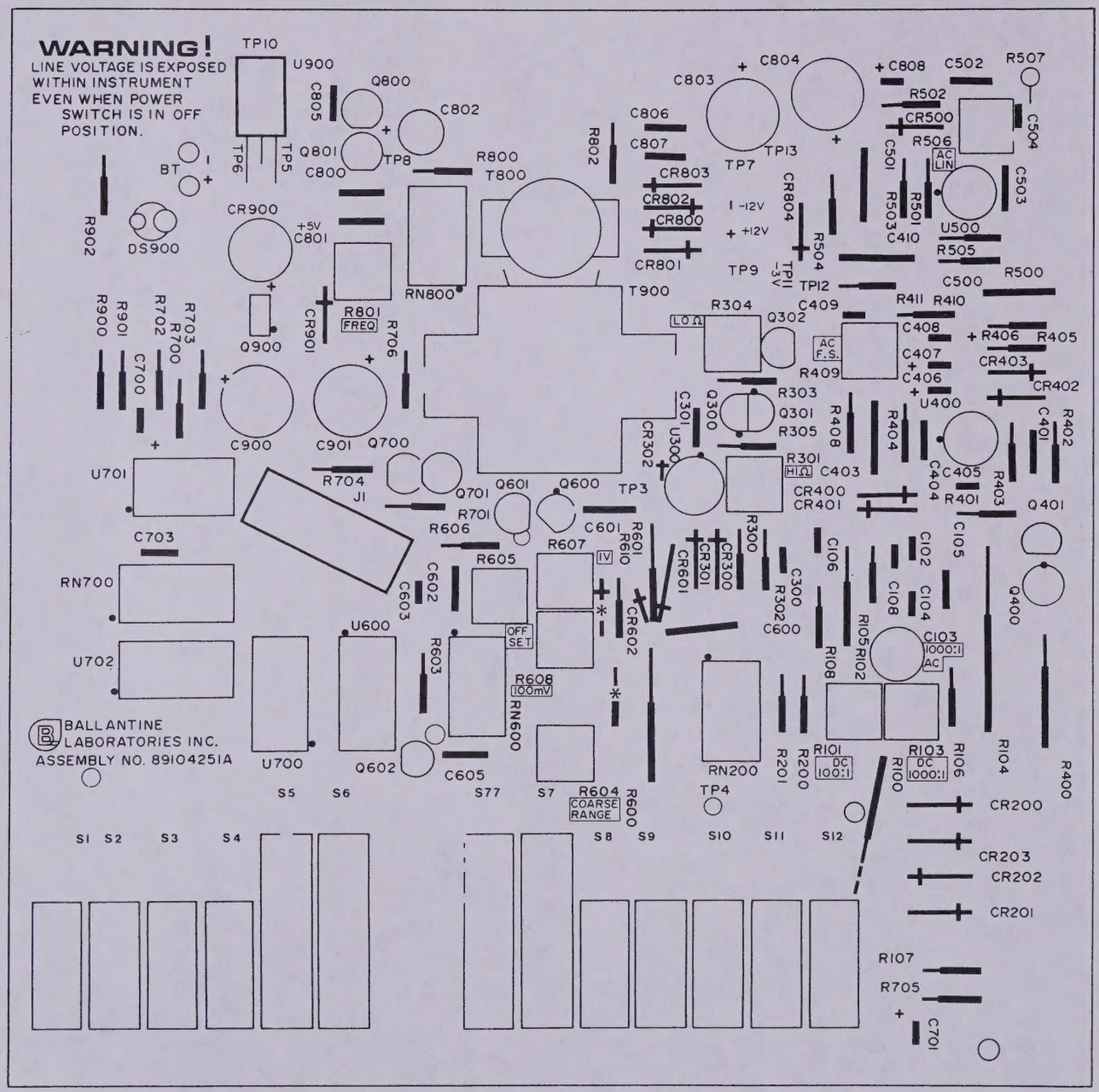
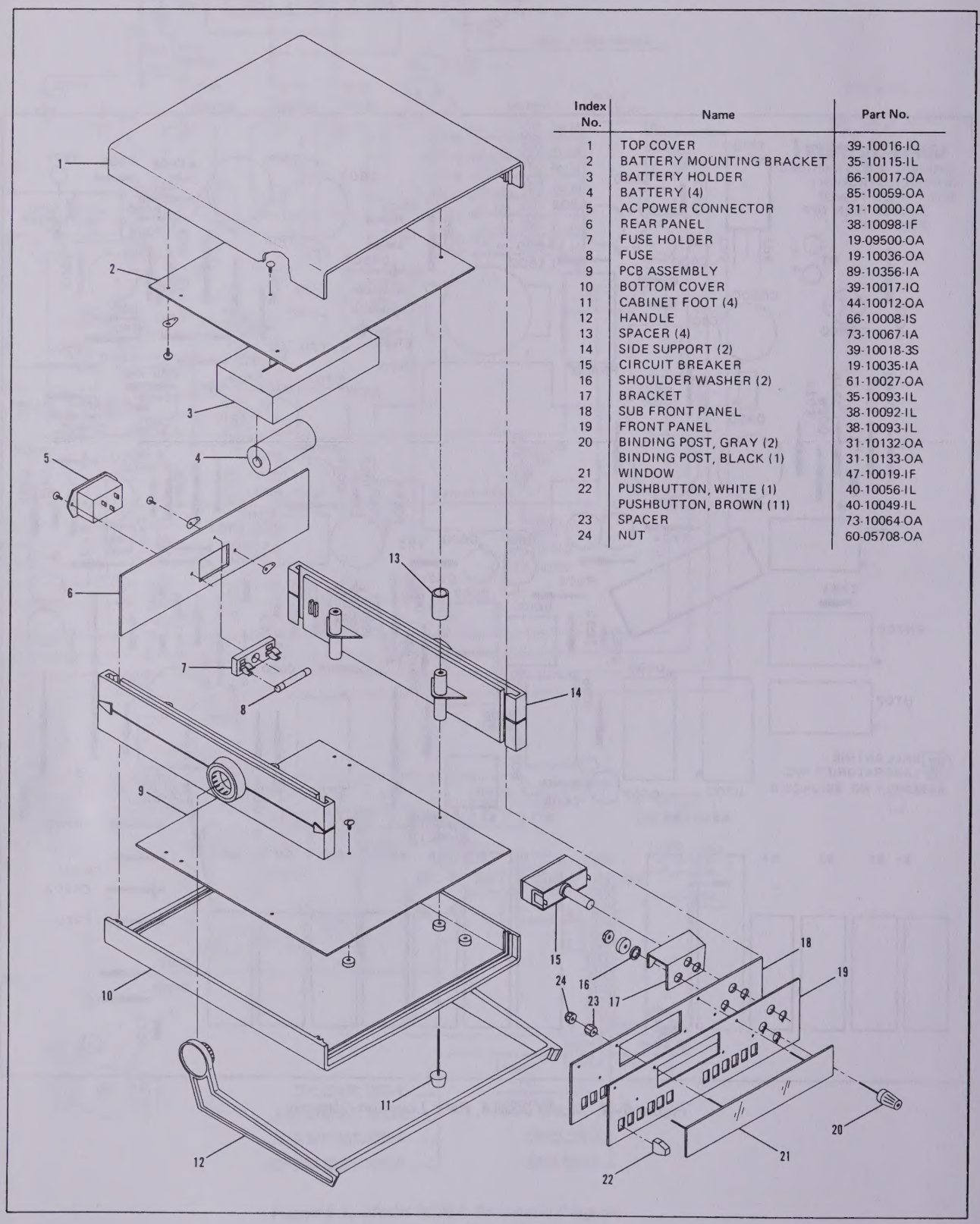


Figure 6–2. Model 3028A, Parts Location Diagram



Index No.	Name	Part No.
1	TOP COVER	39-10016-IQ
2	BATTERY MOUNTING BRACKET	35-10115-IL
3	BATTERY HOLDER	66-10017-OA
4	BATTERY (4)	85-10059-OA
5	AC POWER CONNECTOR	31-10000-OA
6	REAR PANEL	38-10098-IF
7	FUSE HOLDER	19-09500-OA
8	FUSE	19-10036-OA
9	PCB ASSEMBLY	89-10356-IA
10	BOTTOM COVER	39-10017-IQ
11	CABINET FOOT (4)	44-10012-OA
12	HANDLE	66-10008-IS
13	SPACER (4)	73-10067-IA
14	SIDE SUPPORT (2)	39-10018-3S
15	CIRCUIT BREAKER	19-10035-IA
16	SHOULDER WASHER (2)	61-10027-OA
17	BRACKET	35-10093-IL
18	SUB FRONT PANEL	38-10092-IL
19	FRONT PANEL	38-10093-IL
20	BINDING POST, GRAY (2)	31-10132-OA
	BINDING POST, BLACK (1)	31-10133-OA
21	WINDOW	47-10019-IF
22	PUSHBUTTON, WHITE (1)	40-10056-IL
	PUSHBUTTON, BROWN (11)	40-10049-IL
23	SPACER	73-10064-OA
24	NUT	60-05708-OA

Figure 6–3. Model 3028A, Case Assembly, Exploded View

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